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SUPPLEMENTAL IRRIGATION:

PROFIT-MAKER OR LOAD-BUILDER

A Study for
Rural Electrification Administration

by Robert J. M. Matteson

made under the general supervision of
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S U M M A R Y   A N D   R E C O M M E N D A T I O N S

A. THE PRESENT SITUATION: Supplemental irrigation east of the 100th meridian has many potentialities for enlarging farm incomes and building load for REA projects. Though there are very few installations at present, agricultural trends indicate considerable development within the next decade.

1. The consistent failure of natural rainfall to give maximum crops is the basic reason for irrigation in the humid states. Among the chief factors behind this failure are the following: drought years when total moisture is not sufficient, frequency of over-long periods between rains, the numerous rains which are largely ineffective for crop-watering because they come too suddenly and too weakly, the unlikelihood of their being natural moisture at every critical period of plant growth.

2. When crops have plentiful moisture regardless of precipitation, their grower receives certain advantages over the non-irrigating farmer. His crops are insured against drought, and they are likely to be both larger and better in quality. More than that, more crops per season are likely and there are certain miscellaneous benefits: chemical and bacterial action of soil accelerated, "caking" is checked, pests and diseases are hindered and some systems give frost protection.

3. Supplemental irrigation could use a tremendous amount of electrical current, the potential national load being 7.5 billion kwh per year and potential REA project load being 6.5 million kwh per year. Electric pumping at moderate rates is preferable to gas-engine installations. The average crop-watering unit will require a 3hp motor and about 500 kwh of current per season. The mid-west and mid Atlantic states are best suited to supplemental irrigation development.

4. Various conditions — besides rainfall inadequacy — must exist wherever supplemental irrigation is advisable. Most important of these conditions are: ample water supply, proper soil and terrain, "water-requiring" crops, an excess of income over outgo.

5. There are nine methods of supplemental irrigation: subsurface, overhead sprinkler, portable sprinkler, revolving sprinkler, perforated pipe, porous hose, furrow, border and flood. Selection of the proper system depends upon such factors as: crops, terrain, soil, etc. No matter what technique is used, some things are always necessary: pump, piping, motor, etc.

6. Supplemental irrigation is financially feasible for most growers. Installation and operation costs are high, but the large returns more than make up for this expense. Operating costs per acre-inch of delivered water decrease as plots are larger and total volume of water, greater. The average grower receives a net increase in income of about $30 per season from applying supplemental crop-water.

7. Though supplemental irrigation is at present little used, the coming intensification of agriculture and the continuing downward tendency in rainfall indicates grounds for expansion. The two systems which will likely be used most -- because they combine efficiency with economy -- are porous hose and revolving sprinkler. Other probable trends are: "package" merchandizing of small-scale irrigation equipment, increase in crop watering done at night with off-peak current, a large expansion in the field of the suburban or "side-line" kitchen-garden installations.

B. A SUGGESTED REA PROGRAM. To get for its projects any of the vast potential load that would come from wide acceptance of supplemental, REA must carry on an active "campaign" of research and selling. The details of such a program will involve considerable planning by the Utilization Division, but it is possible to foresee certain basic essentials.

1. More research into personal feasibility and load possibilities is necessary before a large-scale "selling" effort can be inaugurated. Several sample installations should be installed immediately and records kept of cost, consumption, returns, etc. Scientific "test-plot" investigations might be conducted by other Department of Agriculture agencies or by REA with NYA labor.

2. The initial emphasis should be upon small, kitchen-garden installations and upon inexpensive but serviceable systems like

porous hose and revolving sprinkler. Small installations are easier to "sell" and will provide their own sales talk for eventual larger units. The two systems suggested are more universally usable than any others and also can be bought as "package" merchandize.

3. REA should put out leaflets, flyers, "News" articles, etc. concerning the advantages of supplemental irrigation. The campaign would also be forwarded by a manual for project superintendents similar to that put out for the "Electric Brooder" drive.

4. Many members should be given initial financial aid to install crop-water pumping systems. This might be done through project loans of the wiring type or through EFHA assistance. Borrowers should be advised to practice cooperative buying.

5. Several miscellaneous points should be kept in mind. Field representatives should "play up" supplemental irrigation. Other Department of Agriculture agencies should cooperate in the campaign. In the beginning certain trial areas should be selected for intensive selling.

INTRODUCTION

Small-scale, separate-farm irrigation throughout the humid East -- neglected till recently in the preoccupation with the large-scale, collective Western variety -- decidedly enlarges both rural incomes and electrical consumption.

Supplemental irrigation -- so-called because it represents water in addition to rainfall -- means larger and better quality crops. Plentiful soil moisture -- needed especially by various fruits and garden vegetables -- is sustained during dry spells and at "critical periods" of plant growth. Not unusual is the experience of an Iowa grower who received 21.8 pounds of tomatoes per unirrigated plant and 44.4 pounds per irrigated.

To rural electric distribution lines offering reasonable rates, supplemental irrigation means a larger and better balanced power load. Energy for water-pumping, an essential of nearly every irrigation layout, is supplied more cheaply by electricity at $.02 per kwh and below than by the more commonly used gasoline. R. E. Horton, the eminent hydrologist, estimates that electric-pumping irrigation would consume 7,500,000,000 kwh every year if used on one-half the humid-state acreage needing and susceptible to supplemental water. He suggests, moreover, that much of this consumption could be off-peak since irrigation is not only a summer undertaking but also one well adopted to night operation.

Because supplemental irrigation does increase both crop returns

and power load -- and various Experiment Station tests have proven its effectiveness -- it should be of substantial interest to project members, project associations and REA itself. Consequently, in this paper we are presenting for your consideration a summary of available literature and opinion on the subject. Among the topics discussed are the needs and advantages of supplemental irrigation, the possibilities of extending the practice, ways in which REA may foster that extension.

We sincerely hope that this presentation may lead the organization to make more serious utilization efforts in the supplemental irrigation field. Such efforts would assist the farmers in using their electricity productively, as well as assist the cooperatives in repaying REA.

I. THE EAST NEEDS IRRIGATION

The consistent failure of natural rainfall to give maximum crops is the basic reason for irrigation in the humid states. According to a table prepared by O. E. Robey of the Michigan Extension Service, only sixteen of the last seventy-five years have approached giving the twelve inches of water necessary between May 1 and September 1 for moderately good production. Even in seasons with high total fall, there may be several rainless periods longer than a week with resulting damage to various susceptible plants. Sometimes otherwise sufficient and evenly distributed rainfall, fails at certain "critical periods" of plant growth. The several extremely severe droughts of this decade are responsible for much of the current interest in the topics.

A. GENERAL SHORTAGE OF MOISTURE

Maximum crops -- and consequently the maximum income from a farmer's expenditure of labor and money -- are obviously not possible when the total moisture available during a growing season is not sufficient for unstunted growth. In the humid territory East of the 100th meridian, as well as in the arid West, this is frequently the case as Robey's figures have already suggested. Such a lack of moisture exists when the entire year is dry or when

3. [illegible]

[illegible] reason for irrigation in the humid states. [illegible] by O. E. Robey of the Michigan [illegible] there may be several rain- [illegible] falls at certain "critical periods" of plant growth. The several extremely severe droughts of this decade are responsible for much of the current interest in the [illegible]

4. [illegible]

maximum crops — and consequently the maximum income from a farmer's expenditure of labor and money — are obviously not [illegible] is not sufficient for unrestricted growth. In the humid territory east of the 100th meridian, as well as in the arid west, this is frequently the case as Robey's figures have already suggested. Such a lack of moisture exists when the entire year is dry or when

little water is available from May to September.

Various statements, gleened from numerous articles on the subject, show that the frequent absence of adequate annual rainfall is no fanciful theory. An orchardist in Michigan states that "three years out of five lack enough rain to grow satisfactory apples." A study by Clive C. Bell, Rural Electrification Engineer of the Wisconsin Public Service Corporation, revealed that, during the six years beginning with 1930, sixteen Wisconsin counties averaged only one year with near-sufficient rainfall. A comprehensive rainfall and run-off survey conducted by the Department of Interior shows a marked trend towards lower average annual precipitation and particularly lower average May-to-September precipitation throughout a good share of the humid region.

B. OVER-LONG SPACE BETWEEN RAINS

More important and consistent than general moisture shortage, as a factor in rainfall's inadequacy, is the length of periods between satisfactory rains. Studies conducted by the Office of Experiment Stations and by O. E. Robey reveal that every growing season contains several rainless stretches, of ten days or more duration, which can be decidedly detrimental to certain crops. Because of that condition supplemental irrigation can be an income-raising investment in wet years as well as dry.

[illegible]

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[illegible]

[illegible] as a factor in rainfall's inadequacy, is the length of periods be-[illegible] investment in wet years as well as dry.

There are many concrete statements by farmers and experts to back up the above analysis. Clive C. Bell, cited earlier, states that most Wisconsin farmers affirm that "There's at least one period during every growing season when an inch or more of water would mean a bigger and better crop." A chart compiled by Robey shows that 1928, to pick a typical "normal" summer, has three ten-day-plus rainless stretches as follows: June 6-9, July 1-14, August 3-19. By considering days after a fortnight without an inch of rain as harmfully dry, Milo B. Williams, a Department of Agriculture investigator, estimated that there were forty days per average humid-area growing season when supplemental irrigation would be beneficial.

C. RAINS OF WRONG TYPE

Besides inadequacies due to long-run shortgage or poor distribution, rainfall also falls short of maximum water contribution to plant growth because it frequently comes too suddenly or too weakly. "A dashing rain, according to Robey, though amounting to three-fourths of an inch or more has a high percentage of run-off and little penetration on the high land where it is most needed." On the other hand, a gentle rain of one-fourth inch or less does not have enough volume for sufficient penetration. Since a large portion of the summer moisture comes either as a driving or gentle rain, irrigation can be needed even

when records of amount and timeliness indicate perfect rainfall conditions.

D. ABSENCE OF RAIN AT "CRITICAL PERIODS"

If rainfall were uniformly excellent in intensity, as well as general plentitude and well-spaced distribution, it still might be advantageous to supplement it because of the added moisture desirable at certain "critical periods" of crop growth. This fact is further reason for stating that humid-area irrigation can benefit growers of several particularly susceptible plants even in years of optimum natural moisture conditions.

The "critical periods" come at various intervals in the life of various crops. Generally speaking, however, germination, transplantation, and filling out are the times when the most water is required. Suggestions in Farmer's Bulletin #1635 indicate the "critical periods" for several plants: "field corn, one irrigation at ear-setting stage; sweet potatoes, one irrigation when vines start and one or two a fortnight before harvesting; strawberries, once every three days at time of fruiting."

II. IMPROVED CROPS

The inadequacies of natural rainfall, then, are the reasons for supplemental irrigation. When crops have plentiful moisture regardless of precipitation, their grower receives certain advantages over the non-irrigating farmer. He no longer fears the perpetual scepter of drought disaster. His harvest is larger, of better quality, and more lucrative. He may be able to grow two crops instead of one. Those benefits and others are the subject of this section.

A. CROP INSURANCE

Supplemental irrigation insures the farmer's crops against failures due to general moisture shortage or ill-distributed rainfall. The operating costs of the installation — including charges for interest and depreciation — represent the rate which the farmer has to pay for that insurance. For a service, such as this, which may prevent hundreds or thousands of dollars loss, $35.00 per acre per season — a high estimate of average humid-area irrigation costs — is certainly not an excessive payment.

Indeed that payment seems exceedingly low when one reads of irrigators making big profits while their neighbors' crops fail almost completely. Scott Martin of Pekin, Indiana, for example, not only secured 246 crates of strawberries per acre

in 1936 while his fellow-growers were averaging 41 crates, but also obtained a much higher percentage of top-grade fruits. An Ohio potato irrigator averaged 345 bushels per acre with 290 bushels being large, as contrasted to his neighbors 200 bushels average with 160 large.

B. LARGER CROPS

Expenditures for supplemental irrigation, however, result in the positive advantage of larger harvests as well as the negative benefit of drought insurance. The extent of the increase varies with the crop, the thoroughness of irrigation, the general cultivational practices. Sometimes the increase is so great as to make the per unit cost of the irrigated produce almost identical with that of the non-irrigated, thus in effect canceling out the additional expense.

A few examples selected from nation-wide reports of humid-region irrigation experiences will illustrate the general statements above. The per-acre yield of an Ohio orchard was 360 bushels on irrigated plots and 290 on unirrigated, the cost being $.43 per bushel of irrigated fruit and $.38 per bushel of non-irrigated. Beans, grown in the humid sections of Oregon, averages 10.32 tons per acre unirrigated and 15.23 tons per acre irrigated. An Iowa experiment showed that irrigated tomato production is 67.4 per cent greater than non-irrigated. Robey's investigations in Michigan revealed that porous-hose irrigation increased crop yields from

50 to 200 per cent. The following table summarizes the results of twenty-five years of supplemental irrigation in a humid section of Oregon:

Oregon Irrigation

Crop	Trial period	Avg. irrigation (inches)	Yield Per Acre (T. or bu.) Not Irrigated	Irrigated	Gain per acre	Gain per acre in.
Alfalfa...	1909-32	10.50	3.62	5.83	2.21	0.21
Red Clover	1908-32	8.15	4.17	6.25	2.08	.26
Alsike....	1914-32	8.44	1.92	4.01	2.09	.25
Grass.....	1915-24	11.20	3.33	5.13	1.80	.16
Potatoes..	1907-32	4.12	134.00	192.92	58.92	14.30
Beans.....	1911-32	3.35	10.32	15.23	4.91	1.47
Corn......	1907-32	5.80	6.47	8.93	2.46	.42
Kale......	1911-14	4.33	10.61	13.95	3.34	.77
Beets.....	1908-14	4.50	10.98	15.61	4.63	1.03
Fibre Flox	1927-32	4.00	1.68	2.36	.68	.17
Gen.Av....	---	6.44	---	---	---	---

C. <u>BETTER QUALITY CROPS</u>

Supplemental irrigation acts positively not only in enlarging crop yield but also in producing better quality crops. In the Ohio orchard cited above, irrigated apples were worth $[illegible] per bushel and unirrigated $.51. In the humid section of Washington, the average weight of cabbage heads from irrigated patches was 5.6 lbs., from unirrigated -- 3.5 lbs. Various potato growers in Michigan and Wisconsin have found that their production of number one has

[illegible] per acre. The following table summarizes the results of [illegible] irrigation in a humid section of [illegible]:

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	—	[illegible]	—	—	—	—

[illegible]

[illegible] crop yields but also in producing better quality crops. In the Ohio orchard cited above, irrigated [illegible] and unirrigated [illegible]. In the [illegible] section of [illegible], the av- erage [illegible] [illegible] [illegible] and Wisconsin have found that their production of number one has

more than doubled, while number two yield has remained stationary and number three has diminished. Such examples could be multiplied indefinitely but those serve to make the point.

D. MORE CROPS PER SEASON

As well as fostering larger and better crops, supplemental irrigation also tends to produce more crops per season. One irrigator, for example, was able to have cabbage, spinach and lettuce from one planting; spinach, peppers and cauliflower from a second. A bulletin issued by the New Jersey experiment station reveals that 184 non-irrigating commercial vegetable growers average 1.5 crops per year on their entire acreage as contrasted with irrigating growers who average 1.9 crops per year.

E. MISCELLANEOUS ADVANTAGES

Besides the various benefits already mentioned, supplemental irrigation accomplishes other things. By providing plentiful soil moisture, it accelerates certain helpful chemical and bacterial activities within the soil. It softens clods and dissolves plant foods, thus checking unproductive "caking". According to W. L. Powers of Oregon State Agricultural College, "Humid-area irrigation is an aid to deep or early plowing, intensive cropping, and enables the operator to prepare the land for planting at any time."

There are several additional benefits associated with the "spray" irrigation technique. The spread of crop pests and diseases

may be checked by frequent washings with the supplemental water. Frost protection may be given by continuous watering when the temperature falls as much as five degrees below freezing.

III. HEAVIER LOAD

Those crop-improving contributions of supplemental irrigation, however, are a somewhat indirect reason for its interest to REA. Being more than "just another cultivational skill", the practice not only adds to farm prosperity -- and consequent ability to pay for current -- but also directly increases load by demanding considerable energy for its own operation. Citation has already been made of R. E. Horton who suggests -- probably conservatively -- that supplemental irrigation might well require 16,000,000 horsepower of electricity per season.

Such a consumption as that suggested would be far exceeded if it were possible or profitable to power with electrical energy all the humid-area irrigation units which may some day be installed. There are a few cases, however, where gravity can be utilized and many, where gasoline engines are less expensive. Those irrigated plots which do have electric pumping consume a surprisingly heavy amount of current -- likely consumption being about 185 kwh per acre per season.

Electricity as the energy for supplemental irrigation, then, will be the subject of this chapter. There will be sections devoted to electrical power's advantages over gasoline, the likely demand for motors and current, the characteristics of Eastern irrigation

as load for REA projects. Left to a later chapter, however, will be a proposed program by which REA might take advantage of this potential load.

A. ELECTRICITY VS. GASOLINE

Although electric motors for supplemental irrigation pumping tend to cost more than gasoline engines, electricity at moderate rates is likely to have various assets which outweigh that initial disadvantage. Therefore, to understand the relative merit of the two energies -- and consequently the service or disservice which REA would be doing farmers and itself by "pushing" humid-area irrigation -- it is necessary to analyze, also other factors besides initial expense. Among those "other factors" are: extra-irrigation uses for the motor, operating charges, and cost of maintenance.

1. INITIAL EXPENSE, which we analyze as the first factor, has already been termed higher for electric installations than for gas engines. This higher first cost springs from the necessity of stringing special lines to irrigation fields as well as from a differential in the price of motors.

a. Motor Costs. Within the "up-to-five-horsepower" range, which satisfies the horsepower requirements of most Eastern irrigation installations, electric motors are considerably more expensive than gasoline engines. In new models, the former cost

about 15 per cent more than the latter, with $75 and $66 respectively being likely prices for three horsepower units. Another significant consideration is the ease and cheapness with which one can acquire rebuilt and second hand automobile motors -- desirable despite their over-heavy power capacities. As a note of general information it might be added that within the above-five-horsepower range -- where energy consumption is too heavy for most REA facilities -- this cost differential tends to disappear and on new motors of higher horsepowers even to go the other way.

b. Wiring Costs. The special wiring which electric pumping irrigation may require is another reason why initial expenditures tend to be less for gasoline installations. O. E. Robey points out, for example, that "very often it is necessary to construct a power line some distance from the buildings to the source of water supply." Virgil Overholt, an Ohio authority, lists as a deterrent to more electrified installations the fact that "where portable irrigation is used the equipment must be changed from field according to the rotation." In the case of unusually large plots requiring higher horsepowers than single-phase lines can safely carry, there would be the additional necessity of substituting three-phase construction.

2. EXTRA-IRRIGATION USES for either a gasoline or electric motor are many. One of the assets counteracting electricity's higher initial cost, however, is the latter's probable adaptibility to slightly more functions and its somewhat greater efficiency. In choosing a motor for irrigation, therefore, a farmer should place considerable weight on how many other uses -- such as threshing, insect spraying and plumbing system pumping -- will be given his new machinery.

This "other uses" angle of motor selection is especially significant to REA. It means that supplemental irrigation besides being a load-builder and income-producer, is also directly related to various lines of present utilization efforts. It may be possible, for example, to sell a project member on plumbing and irrigation as inter-related benefits from one expenditure even though he might "balk" at accepting plumbing as an independent electrical use. Certainly a farmer who already has an electric motor for plumbing, feed grinding, etc. -- r a gasoline engine, for that matter -- should readily understand the wisdom of spending enough more to use the same motor in watering his crops.

3. OPERATING COSTS, representing another asset for an electric installation, are usually higher for gasoline engines.

Authorities are nearly unanimous in believing that electric motors deliver more water per horsepower-hour[1/] than do internal combustion apparatuses. Though fuel charges -- electric current by kwh and gasoline by the gallon -- are sometimes higher per horsepower-hour on an electrified installation than on a gas-powered one, this better water-delivery efficiency of the electric motor nearly always results in the per-acre-inch cost of electricity being less than gasoline. Discussed briefly below are these two matters -- efficiency and rates -- which determine operating expenses.

a. Efficiency. The electric motor's water-delivery superiority over a gas engine of equal strength has several bases. Most important, it will maintain the high, constant speed which most pumps require for optimum operation. Secondly, its size is usually better adapted to the pump and required water volume than the gas engine which often has such excessive horsepower that fuel consumption is extra heavy and coordination with the pump is poor. Thirdly, the electric motor demands much less attendance and is considerably more dependable than the internal combustion apparatus.

b. Fuel Charges. Until the price of electricity exceeds 2½¢ per kwh, electric pumping is likely to be less expensive

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1/ Horsepower-hour -- a unit for applying the same time conditions to motors of varying type and varying power. Thus 5-horsepower-hours might mean a 5-horsepower motor run for one hour, a 1-horsepower motor run for five hours, etc.

than gasoline. Because many "high-rate" utilities have disregarded that fact, "internal combustion" pumping is prevalent in many of the humid region's most irrigatable sections. Because REA cooperatives and other "low-rate" companies can heed that same fact, they have the opportunity of developing an excellent load simply by doing their consumers a great favor. Perhaps a table prepared by C. E. Robey shows better than anything else the relation between charges for gallons of gasoline and kilowatt-hours of electricity:

Pumping Costs For Acre-Inch Of Water 1/

Head in feet	Gas Engine (Price Per Gallon)				Electric Motor (Price Per kwh)			
	10¢	12¢	14¢	16¢	1¢	2¢	3¢	5¢
20	$0.09	$0.10	$0.12	$0.14	$0.04	$0.09	$0.14	$0.23
30	.13	.15	.19	.21	.06	.12	.17	.29
40	.19	.22	.25	.30	.09	.18	.27	.45
50	.23	.26	.30	.34	.11	.23	.34	.57
60	.27	.32	.36	.42	.14	.27	.40	.63
70	.31	.38	.43	.50	.16	.32	.48	.79
80	.35	.42	.48	.56	.18	.36	.54	.91
90	.39	.48	.54	.63	.21	.41	.61	1.02
100	.45	.54	.63	.71	.23	.45	.68	1.13
125	.54	.65	.76	.88	.28	.57	.85	1.42
150	.66	.79	.93	1.08	.34	.68	1.02	1.69
175	.77	.92	1.09	1.24	.40	.80	1.20	2.00
200	.88	1.08	1.22	1.42	.45	.90	1.35	2.26

1/ Table is based on consumption of an averaged-sized plot -- as illustrated in detail on page 32 -- operating under normal conditions. Pumping costs may be considerably different on a plot smaller or larger than the average range; the same holds true for an installation with a power unit too large for the pump, equipment out of adjustment, or an unsuitable pump.

4. MAINTENANCE COSTS represent a minor factor in analyzing the relative desirability of gas engines and electric motors in supplemental irrigation. Neither is likely to break down completely and both cost little to fix. Gas engines are somewhat less durable but most farmers can do their own repair work and thus avoid the occasional cash outlays that come when electrical apparatus needs doctoring. All things considered, this factor neither lessens or heightens the preferred rating given electric motors because of their lower operating costs and widespread extra-irrigation uses.

B. ELECTRICITY IN USE

If low-rate electricity is deemed to have certain advantages over gasoline as power for supplemental crop watering, the logical next interests of both the prospective irrigator and REA are what size motor will be required and how much current will be consumed. Those interests can only be satisfied by considering determining factors as the size and location of the plot to be irrigated, the frequency and rapidity with which water will probably be applied, and the particular method of water distribution (permanent overhead, porous hose, etc.) demanded by the terrain, climate and crop. Though the variability and complex inter-relations of the above factors tend to give different answers on every installation, a normal irrigation unit in an REA project area is likely to have approximately a 3-horsepower motor and a 500 kwh per-season

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consumption. Perhaps estimates for any specific undertaking will be suggested by the following discussion of how plot location, irrigation frequency, etc. -- as expressed in terms of necessary gallons per minute, total feet of head, etc. -- do decide motor horsepowers and kwh consumption.

1. MOTOR HORSEPOWER should vary directly with gallons per minute and feet of head. A one-acre garden not more than 100 yards from the water supply, to illustrate, might be powered very satisfactorily with one horsepower. For a six-acre plot about 400 yards from water, however, an irrigator would probably want five horsepower -- considered by some as the limit safely carried on REA single-phase construction. To understand what motor to get for what installation, therefore, it is necessary to analyze how plot size and other matters underlie gallons per minute (GPM) needs and how distance-from-water and other matters determine total feet of head. In going through this analysis a reader might well bear in mind, for the sake of knowing the general GPM and head range of supplemental irrigation, that the typical installation requires a flow of about 75 gallons per minute and a head of about 90 feet.

a. Gallons Per Minute. Distribution method and time allotment for irrigation are the variables, besides plot size, which determine necessary pumping speed. In the first place, overhead spray, revolving sprinkler and other irrigation systems which are economical

with water naturally require less gallons per minute to do a given job in a given time than do systems, like furrow and flood, which are characterized by considerable waste. Secondly, it is evident that an irrigator who wants to cover an acre with an inch of water in three hours will have to pump faster than one who is content to do the same thing in six hours. Finally, it is also plain that irrigation of a five-acre plot in a given number of hours will require more rapid pumping than would the watering of a two-acre plot in identical time.

As primary determinant of GPM for the individual grower with limited irrigation area, the time allotment for supplemental watering seems to deserve additional explanation. In making their decision on this factor, most successful irrigators plan to give their plot one complete inch-depth application about every ten days. Many of them with large installations do not do this, however, through a system which finishes the entire job in a few hours. Instead they have motors and pumps with only enough capacity to give complete areal coverage on a section-per-day-rotation basis. According to a <u>C.R.E.A.</u> <u>Bulletin</u>, this "piecemeal" system brings the farmer several economies: low installation cost, non-idle equipment, lower-priced energy, etc. For a REA cooperative or other utility supplying the power, the system also has advantages: it means a steady load; it means more installations can be powered by motors used safely with single-phase construction.

Considering time allotment and the two other factors as determinants, it is possible to estimate the gallons-per-minute that may need pumping on various sized plots which REA project members would be likely to irrigate. Some probable GPM requirements for fields of representative acreages are indicated in the following list, together with the time arrangement of actual watering within each ten-day irrigation cycle: one-half acre, one-seven hour application -- 35 GPM; three acres, three seven-hour applications -- 70 GPM; seven acres, four six-hour applications -- 140 GPM; ten acres, five six-hour applications -- 165 GPM. As explained in the next few pages, those gallon-per-minute requirements may be translated into probable horsepowers and potential load -- a typical head of 70 feet is assumed for the translation here -- to give a list of figures which should interest REA: half-acre with 35 GPM -- 1-horsepower motor and 81 kwh per season; three-acres with 70 GPM -- 2½-horsepower and 420 kwh; seven acres with 140 GPM -- 4½-horsepower and 850 kwh; ten-acres with 165 GPM -- 5-horsepower and 1,190 kwh. The estimates are not extended upwards beyond ten acres, incidentally, because ordinary REA construction could not safely serve the facilities which are required for larger installations.

b. <u>Feet of Head</u>. As noted in introducing this section, the amount of gravity and friction resistance to pumping is the

other factor -- besides gallons per minute -- which determines the necessary capacity of irrigation motors. This resistance, or "head" as it is technically termed, is based on four variables: vertical distance from water level to pump, vertical distance from pump to highest point in field, friction loss in pipe line conveying water from source to distribution system, pressure required for optimum operation of the particular distribution system. The greater the sum to which those variables add -- and in this is their significance to the prospective irrigator and to REA -- the larger the motor that will be needed and the more numerous the kilowatt-hours that will be consumed.

The first two influences, vertical distances from water to pump and from pump to field, need little explanation. Every foot that water for irrigation must be elevated means, in the language of hydrodynamics, another head-foot of resistance to pumping. Because of that one-to-one relationship, "vertical-distance" characteristics of plot location and terrain have perhaps more weight than any other one influence in determining whether horsepower capacity and kwh consumption for a given plot will be relatively small or large.

Pipe-line friction, the third variable influencing total head, depends on the relationship between three factors. Firstly, gallon-per-minute flow -- determined by the considerations explained

in the last subsection effects pipe-resistance directly, an increase in GPM rate causing an increased friction loss and vice versa. Secondly, pipe length -- decided by an irrigation plot's distance from the water supply -- also has a direct effect upon conveyor-line resistance, a long pipe involving more friction loss than a short. Finally, an inverse influence diameter meaning less resistance and vice versa. Because this last factor is completely a matter of an irrigator's own decision, the pipe line resistance variable can be controlled to keep total head at the most desirable minimum, as indicated in the following estimated diameters for several plots likely to be typical of REA installations: one-half acre, three hundred feet from water -- 1½" pipe to carry 35 GPM with 35 foot friction loss; three acres, five hundred feet from water -- 2" pipe to carry 70 GPM with 55 foot friction loss; seven acres, seven hundred feet from water -- 3" pipe to carry 140 GPM with 40 foot friction loss; ten acres, twelve hundred feet from water -- 3½" pipe to carry 165 GPM with 44 foot friction loss.

Besides pipe-line resistance and vertical lift as determinants of total head, there is -- as mentioned previously -- the operating pressure required for the particular distribution system. This pressure varies from an equivalent of fifty head-feet for

sprinkler irrigation, through twenty-five head-feet for porous hose and fifteen for perforated pipe, to nothing at all for the surface methods. The selection of a system -- and consequent "distribution" head -- depends on what method is best adapted to the terrain, crop, plot size, etc.

Through proper consideration of the four variables described, it is possible to make estimates of likely head and -- directly significant for REA -- of resulting likely motor horsepower and current usage. Thus, a one-half acre, "three-hundred-feet-from-water" plot with the revolving sprinkler system and an "above-water" elevation of twenty-five feet might have 110 head-feet resistance to pumping. Translated into motor requirements and probable load (of course a reasonable GPM flow has to be assumed to do this here and later) such a head might mean a motor of 2-horsepower and an annual consumption of 125 kwh. The following list summarizes similar estimates for several other representative installations: three acres, five hundred feet from water, forty feet above water, porous hose -- 120 feet, 4-horsepower, 740 kwh; seven acres, seven hundred feet from water, fifteen feet above water, perforated pipe -- 85 feet, 4½ horsepower, 955 kwh; ten acres, twelve hundred feet from water, twenty feet above water, furrow -- 67 feet, 5-horsepower, 1,050 kwh.

c. Correlating GPM and Head. Having analyzed separately the two factors that determine horsepower of motors likely to be used on REA lines, it now remains to show the inter-relationships between the two influences. A table prepared by O. E. Robey reveals these inter-workings better than could a ream of words and indicates just how great a burden the cooperative lines might have to carry under a variety of irrigation conditions. In studying this table two things might well be kept in mind: (1) any situation calling for more than five horsepower should be eliminated from consideration as possible load on REA single-phase construction; (2) because motor capacity is directly related to pump size, it is assumed here and in earlier estimates that the pump as well as the motor is to be corectly adapted -- as explained in a later chapter -- to the peculiar conditions of any particular installation.

Horsepower For Pumping At 50 Per Cent Pump Efficiency

Gallons per minute	Total Head in Feet									
	10	20	30	40	50	60	75	100	125	150
10	.05	.10	.15	.20	.25	.30	.37	.50	.62	.75
15	.08	.15	.22	.30	.37	.44	.56	.75	.94	1.12
20	.10	.20	.30	.40	.50	.60	.75	1.00	1.25	1.50
25	.13	.25	.37	.50	.62	.74	.94	1.25	1.56	1.87
30	.15	.30	.45	.60	.75	.90	1.12	1.50	1.87	2.25
35	.18	.35	.52	.70	.87	1.04	1.31	1.75	2.19	2.62
40	.20	.40	.60	.80	1.00	1.20	1.50	2.00	2.50	3.00
45	.23	.45	.67	.90	1.12	1.34	1.69	2.25	2.81	3.37
50	.25	.50	.75	1.00	1.25	1.50	1.87	2.50	3.12	3.75
60	.30	.60	.90	1.20	1.50	1.80	2.25	3.00	3.75	4.50
75	.38	.75	1.12	1.50	1.87	2.24	2.81	3.75	4.69	5.62
90	.45	.90	1.35	1.80	2.25	2.70	3.37	4.50	5.62	6.75
100	.50	1.00	1.50	2.00	2.50	3.00	3.75	5.00	6.25	7.50
125	.63	1.25	1.87	2.50	3.12	3.74	4.69	6.25	7.81	9.37
150	.75	1.50	2.25	3.00	3.75	4.50	5.62	7.50	9.37	11.25
175	.88	1.75	2.62	3.50	4.37	5.24	6.56	8.75	10.94	13.12
200	1.00	2.00	3.00	4.00	5.00	6.00	7.50	10.00	12.50	15.00
250	1.25	2.50	3.75	5.00	6.25	7.50	9.37	12.50	15.72	18.75

2. KWH CONSUMPTION on supplemental irrigation installations is another subject, like required motor capacities, which holds considerable significance for both the humid-region grower and REA. The average plot of somewhat less than three acres, for example, will use approximately the following: 20 kwh per acre-inch, 55 kwh for each complete application -- likely to be accomplished at least once every ten days, 186 kwh per acre per season, <u>497 kwh for the entire plot per acre per season</u>. Without knowing roughly how much electricity will be used in watering plots of various sizes and locations, the prospective irrigator cannot estimate the financial

feasibility of his tentative undertaking and REA's Utilization Division cannot estimate the probable increase in cooperative load from a campaign to "sell" Eastern irrigation.

Dealt with in the following paragraphs, consequently, are the various factors determining the amount of current used in irrigating humid-area crops. Leaving till later a discussion of increases in project loads, the ensuing material will emphasize the individual aspect of irrigation consumption. Among the featured topics will be the deciding influence of head, equipment and other factors upon kilowatt-hours per acre-inch and of plot size, climatic conditions and other things upon total usage per season.

a. Consumption Per-Acre Inch. Kwh needed for pumping a given amount of water -- let us say the 27,154 gallons comprising an acre-inch -- is somewhat different for every installation. Such variation springs from the plot-to-plot differences in basic determinants of power consumption. These determinants -- as with motor requirements -- are the acreage, location, terrain and soil of the irrigated land. Working through two immediately deciding factors -- feet of head against which irrigation must be accomplished and efficiency of equipment with which irrigation must be accomplished -- the physical characteristics mentioned settle whether per acre-inch pumping costs for any particular installation are prohibitive, moderate, or very low.

Feet of head -- depending on a field's vertical and horizontal distances from water and on the distribution system required by terrain, etc. -- influence pumping consumption more than any other factor. The greater the adverse head, the harder a motor must work to deliver a given amount of water and the more current it consumes, an average relationship being one kilowatt-hour for each 4.5 feet of head against which an acre-inch must be lifted. Because of that direct head-kwh connection, operation of level, near-to-water plots would involve less cooperative load but more individual profit than rolling, far-from-water installations.

Equipment efficiency, variations in which cause the lifting power of a kilowatt-hour to deviate from the 4.5 feet-per-kwh average, is the other influence upon the per acre-inch power consumption of supplemental irrigation. Among the secondary determinants of this efficiency are several matters over which the grower himself can exercise considerable control: the coordination of pump and motor, the plant's state of repair, the excellence of lubrication, etc. Disastrous as slip-ups in those matters can be, however, probably the major determinants are -- as for head-feet-- the physical characteristics of irrigation installations. Because plots with different characteristics demand irrigating plants of different delivery and pressure capacities -- and hence different efficiencies -- two separate irrigators with identical mechanical and cultivational

skill will be very unlikely to get the same amount of pumping power per kilowatt-hour of current used. This relationship between plant capacity as expressed in the horsepower of the motor used, and plant efficiency is illustrated by the following table:1/

Efficiencies Of Different Motors
(Amount of adverse head overcome by one kwh in pumping one acre-inch of water)

Horsepower of Motor	Amount of Head (Feet)	Plant Efficiency (Per Cent)
1	4	42
2	4.3	45
3	4.6	48
4	4.8	50
5	5	52

b. Total Consumption Per Season. Though kwh consumption per acre-inch is the common technical basis for measuring current usage for crop-water pumping, the prospective irrigator or the utility manager — be he cooperative or private — is probably more interested at the beginning in how much "juice" a complete installation is likely to take during the full irrigation season. For the average plot during a normal summer that total consumption — as already has been said — is likely to be about 500 kwh; but for some particular installation during some particular year, the

1/ In the table it is assumed that motors and pumps are perfectly adapted to one another and in perfect running condition.

figures may be anything from 10 to 1,200. Plot size, rainfall conditions, and type of crop are among the more important factors determining how many acre-inch applications must be made and, hence, how much the total consumption figures will be.

Most of the factors influencing seasonal usage are so obvious as to need little explanation. It is self-evident, for example, that water requirements — hence current consumption — are directly related to plot size, that a careful irrigator will waste less water — hence less kolowatt-hours — than one who "doesn't give a damn", that some distribution systems of the surface variety require more water — hence more "juice" — than do economical systems like the overhead sprinkler. It is almost as plain that more current will be used in watering crops which demand much water than those which require little, in irrigating terrains with high run-off than those which have slow drainage, in satisfying soils without good substratum than those which have an impervious layer underneath.

The factor with greatest weight is, of course, the amount of rain that falls and its distribution. In a normal humid-region summer about nine complete applications per season are needed, one every ten days. During a drought year, however, this number may be doubled and during a "bumper-crop" year, halved. Experiences best teaches the irrigator in a particular locale how moist to keep his ground and, consequently, how often to turn on the

"juice" for his irrigation system. This "how-much-water" topic, along with several others mentioned in the previous paragraphs, is somewhat more fully discussed in later chapters.

c. Consumption Table. To show the inter-relations between the major ("plot-characteristic") factors affecting pumping consumption and between the several results, per unit or per season for example, the best device is the table below, which gives likely kwh usage for a number of variously-dimensioned installations. A cursory glance at the per-acre-inch figures, to illustrate, reveals plainly how the larger heads require the greater consumption and how larger plot sizes -- because of acreage's determining influence on equipment capacity -- mean less consumption. The averages, too, because the proportion of large and small areas and high and low heads among actual irrigation plots is the basis for the sample figures listed, have considerable validity as indications of how much increased load an REA cooperative can expect from representative installations. Much of the primary material for this table was drawn from a C.R.E.A. publication, a Washington State Agricultural Bulletin, and a pamphlet by O. E. Robey.

Kilowatt-Hours Used In Supplemental Irrigation

Head	Analysis of consumption	Size of Plot (Acres) .25	.5	.75	.1	2.5	.4	.6	8.5	Averages (2.8)
20	T.P.S.	11.7	22.5	33.3	44.1	103.5	154.8	21.6	275.4	107.7
	P.A.P.S.	46	45.8	45.	44.1	41.4	38.7	36	32.4	40.5
	E.C.A.	1.3	2.5	3.7	4.9	11.5	17.2	24	30.6	12
	P.A.I.	5.1	5.1	5.1	4.9	4.6	4.3	4	3.6	4.5
30	T.P.S.	15.3	30.6	45	58.5	136.8	205.2	286.2	367.2	143.1
	P.A.P.S.	61.2	61.2	60.3	58.5	54.9	51.3	47.7	43.2	54.
	E.C.A.	1.7	3.4	5	6.5	15.2	22.8	31.8	40.8	15.9
	P.A.I.	6.8	6.8	6.7	6.5	6.1	5.7	5.3	4.8	6
40	T.P.S.	25.2	45.9	67.5	88.2	207.	309.6	432.	550.8	21.6
	P.A.P.S.	92.7	91.8	90	88.2	82.8	77.4	72	64.8	81
	E.C.A.	2.8	5.1	7.5	9.8	23	34.4	48	61.2	24
	P.A.I.	10.3	10.2	10	9.8	9.2	8.6	8	7.2	9
50	T.P.S.	29.7	58.5	86.4	112.5	262.8	396	550.8	695.7	274.5
	P.A.P.S.	117.9	117.	115.2	112.5	105.3	99	91.8	82.8	103.5
	E.C.A.	3.3	6.5	9.6	12.5	29.2	44	61.2	77.3	30.5
	P.A.I.	13.1	13	12.8	12.5	11.7	11	10.2	9.2	11.5
60	T.P.S.	35.1	68.4	100.8	132.3	310.5	464.4	648	826.2	323.1
	P.A.P.S.	138.6	137.7	135	132.3	124.2	116.1	108	97.2	121.5
	E.C.A.	3.9	7.6	11.2	14.7	34.5	51.6	72	91.8	35.9
	P.A.I.	15.4	15.3	15	14.7	13.8	12.9	12	10.8	13.5
70	T.P.S.	41.4	81	119.7	156.6	366.3	550.8	766.8	979.2	382.5
	P.A.P.S.	163.8	162.9	160.2	156.6	146.7	137.7	127.8	115.2	144
	E.C.A.	4.6	9	13.3	17.4	40.7	61.2	85.2	108.8	42.5
	P.A.I.	18.2	18.1	17.8	17.4	16.3	15.3	14.2	12.8	16
80	T.P.S.	46.8	91.8	135	176.4	414	619.2	864	1101.6	431.1
	P.A.P.S.	185.4	183.6	180	176.4	165.6	154.8	144	129.6	162
	E.C.A.	5.2	10.2	15	19.6	46	68.8	96	122.4	47.9
	P.A.I.	20.6	20.4	20.	19.6	18.4	17.2	16	14.4	18
90	T.P.S.	53.1	104.4	153.9	200.7	469.8	705.6	982.8	1254.6	490.5
	P.APS.	210.6	208.8	205.2	200.7	188.1	176.4	163.8	147.6	184.5
	E.C.A.	5.9	11.6	17.1	22.3	52.2	78.4	109.2	139.4	54.5
	P.A.I.	23.4	23.2	22.8	22.3	20.9	19.6	18.2	16.4	20.5
100	T.P.S.	58.5	114.3	168.3	220.5	517.5	774.	1080.	1377.	539.1
	P.APS.	232.2	229.5	225.	220.5	207.	193.5	180.	162.	202.5
	E.C.A.	6.5	12.7	18.7	24.5	57.5	86.	120.	153.	59.9
	P.A.I.	25.8	25.5	25.	24.5	23.	21.5	20.	18.	22.5

1/ Figures given here are based on several necessary assumptions: average conditions of rainfall terrain, soil, crop, etc.; correctly chosen pump and motor; proper lubrication and good state of repair. See above discussion for the ways in which consumption is affected by circumstances different than those assumed.

Kilowatt-Hours Used In Supplemental Irrigation

Head	Analysis of consumption	Size of Plot (Acres) .25	.5	.75	.1	2.5	.4	.6	8.5	Averages (2.8)
125	T.P.S.	73.8	144.9	213.3	279.	654.3	979.2	1366.2	1744.2	682.2
	P.A.P.S.	294.3	290.7	285.3	279.	261.9	244.8	227.7	205.2	256.5
	E.C.A.	8.2	16.1	23.7	31.	72.7	108.8	151.8	193.8	75.8
	P.A.I.	32.7	32.3	31.7	31.	29.1	27.2	25.3	22.8	28.5
150	T.P.S.	87.3	172.8	254.7	333.	780.3	11.7	1630.8	2080.8	813.6
	P.A.P.S.	350.1	346.5	340.2	333.	312.3	292.5	271.8	244.8	306.
	E.C.A.	9.7	19.2	28.3	37.	86.7	130.	181.2	231.2	90.4
	P.A.I.	38.9	38.5	37.8	37.	34.7	32.5	30.2	27.2	34.
175	T.P.S.	94.5	203.4	299.7	391.5	919.8	1375.2	1917.	2448.	955.8
	P.A.P.S.	412.2	407.7	399.6	391.5	368.1	343.8	319.5	288.	360.
	E.C.A.	10.5	22.6	33.3	43.5	102.2	152.8	213.	272.	106.2
	P.A.I.	45.8	45.3	44.4	43.5	40.9	38.2	35.5	32.	40.
200	T.P.S.	116.1	238.5	337.5	441.	1035.	1548.	2160.	2754.	1079.1
	P.A.P.S.	465.3	459.	450.	441.	414.	387.	360.	324.	405.
	E.C.A.	12.9	26.5	37.5	49.	115.	172.	240.	306.	119.9
	P.A.I.	51.7	51.	50.	49.	46.	43.	40.	36.	45.
Averages (91.5)	T.P.S.	53.1	105.3	155.7	202.5	475.2	716.4	993.6	1269.9	496.8
	P.A.P.S.	212.4	210.6	207.	202.5	189.9	179.1	165.6	149.4	186.3
	E.C.A.	5.9	11.7	17.3	22.5	52.8	79.6	110.4	141.1	55.2
	P.A.I.	23.6	23.4	23.	22.5	21.1	19.9	18.4	16.6	20.7

1. T.P.S. ---- Total consumption per season
2. P.A.P.S. -- Consumption per acre per season
3. E.C.A. ---- Consumption for each complete application
4. P.A.I. ---- Consumption per acre-inch

C. IRRIGATION AS REA LOAD

Vital as individual pumping consumption is to a prospective irrigator or a rural "high-line" company, the feasibility of a promotional campaign for humid-region crop-watering depends even more upon another "kwh-for-irrigation" matter, -- potential project load from combined individual consumptions. Though this varies from section to section in accordance

with agricultural characteristics, almost everywhere it is stable and surprisingly heavy. By creating a market for off-peak energy and increasing member-incomes so much that more could be spent on current for other purposes, supplemental irrigation would improve the load of REA borrowers in thirty-three states. As explained hereafter, the night and summer valleys in rural power distribution might be evened out and nation-wide kilowatt-hour consumption in REA projects augmented eventually by 60,500,000 kwh per year.[1]

1. QUALITY CHARACTERISTICS of supplemental irrigation load -- steadiness, "off-peakness", and productivity -- are one major reason, then, for the desirability of crop-water pumping on REA lines. Because water is applied slowly and application days vary from installation to installation[2], there are no costly fluctuations in consumption. Because all irrigation is done in summer and much can be done very advantageously during sleeping time[3], many kilowatt-hours of otherwise wasted energy are consumed. Because watered crops are bigger and better, there is -- instead of the almost too customary "greater ease-of-living" -- a marked increase in farm income.

1/ Direct pumping load. No allowance is made for possible consumption increases resulting from irrigators' enlarged incomes.
2/ Differences in crops, terrain, soil, personal preference and other influences cause this variation. Rainfall is not a factor since reference is to installations in the same project area.
3/ Night irrigation is suggested by R. E. Horton. See page

2. LARGE QUANTITY, another common characteristic of crop-watering consumption, is the second major reason for the desirability of supplemental irrigation load. Besides the already-mentioned usage-per-season estimates for a typical installation (490-500 kwh) and for potential total REA installations (60,500,000 kwh), various other approximations -- based ultimately on material of such authorities as Horton, Robey and C.R.E.A. -- indicate the surprising possible magnitude of <u>annual</u> pumping load: overall per-member[1/] average -- 99 kwh, typical 800-member project -- 79,200 kwh, potential increase in present humid-state REA usage -- 14 per cent. Further evidence of heavy quantity consumption is given by various averages of potential irrigation load <u>per month</u>: per member during pumping season[2/] -- 24 kwh, typical project during pumping season -- 16,500 kwh, per member for whole year -- 8 kwh, per project for whole year -- 6,500 kwh. Such estimates are not intended, of course, as a rosy picture of immediately obtainable load but as an indication of what several years of well-planned utilization effort might accomplish.

Though these over-all figures suggest general magnitude, more specific project or section estimates -- consumption for a particular organization or state likely being considerably different

1/ Not per-irrigator.
2/ June, July, August and September are the irrigation months in most states. Southern section is exception.

than the national REA averages -- require consideration of numerous load-deciding variables. Among these factors are six of the "individual-consumption" influences: rainfall, terrain, soil, crops, season length and water availability. Among them, too, are a like number of indirect considerations: markets, income, attitudes, tenancy, irrigation, experience, and familiarity with electricity. Being components of the total setting for crop watering, those influences determine three basic matters: how many members might irrigate, how much water the irrigators might apply, how much current might be used in applying the water. Perhaps the significance of the various influences -- discussed also in other parts of this study -- can best be clarified here by an anlysis of potential load in several projects and sections.

a. Project Analysis[1]: To estimate potential irrigation consumption for any particular REA area, each determinant must be properly evaluated. Various factors would be "high-load influences", for example, when they were as follows: rainfall-scanty, soils-light, crops-leafy, seasons-long, surface water-plentiful, markets-large and nearby, incomes-high, attitudes-forward-looking, farm tenancy-low, electrical experience-considerable. "Low-load tendencies" would be exhibited

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1/ Membership or consumption figures given in this subsection are from the March 1939 Operations report.

when opposite adjectives applied. Familiarity with irrigation practices might be classed as another "high-load influence", were it not for the fact that growers with gas engine installations sometimes hesitate to replace them. A mixed force is exercised by terrain conditions; with ruggedness making for few irrigators but high individual consumption, while levelness does the opposite.

(1) Let's look at Pennsylvania-17-Armstrong, a 733-member project just north of Pittsburgh to see how those numerous variables affect the potential irrigation load of a representative Eastern borrower. There are various "high-load" influences: light soils, "general-farming" crops like table vegetables and berries, plentiful ponds and streams, good markets in nearby urban areas and along numerous traversing highways, and the large percentage of farms owned by their operators. Counterbalancing those tendencies, however, are several factors: low average incomes ($436 net cash per year), conservative attitudes, lack of irrigation experience, and slowness in adopting electricity (present consumption per member -- 45 kwh per month). A less definite one-way influence is given by the other variables: a normal humid-region rainfall and summer requiring about nine supplemental-water applications for optimum harvests, and a rugged terrain which discourages irrigation but makes individual consumption heavy. In combined force those twelve factors seem to indicate a potential

yearly irrigation load of moderate dimensions[1/]: 150 irrigators -- 20 per cent of membership, 443 kwh per irrigator, 91 kwh per member, 66,450 kwh total.

(2) Comparison with that Eastern situation is supplied by Georgia-67-Bacon, a representative Southern borrower with 984 members in southeastern Georgia. There are only three clear-cut "high-load" factors: long growing season, numerous rivers, and an average income surprisingly good for that section ($814 net cash). Four influences, in contrast, work definitely toward a low consumption: plentiful rainfall (26" in seven growing months), conservative attitudes, large amount of tenancy (60%) and a decided lack of irrigation experience. The other factors and their affects vary as indicated here: level terrain -- large-scale installations but low consumption per-acre inch; eroded, sandy soils -- not much land fit for irrigation but high consumption on what is; cotton and tobacco specialities with some truck --irrigation not needed for most crops; no city markets but considerable highway demand -- numerous installations for roadside produce. In the situation indicated by those variables, yearly irrigation load would probably never average more than the following: 125 irrigators -- 13 per cent of membership, 370 kwh per irrigator, 47 kwh per member, 46,250 kwh total.

1/ In comparing irrigation loads of different projects, the factors usually deserving most emphasis are: per cent of membership irrigating, consumption per irrigator, consumption per member. The other considerations -- number of irrigators and total load -- are influenced strongly, of course, by differences in the membership size of different borrowers.

(3) Better adapted to supplemental irrigation development than either the Pennsylvania or Georgia borrowers, are various mid-western projects -- of which Indiana-24-Carroll is perhaps representative. With 955 consumers in northwestern Indiana, this organization's potential pumping load is influenced towards largeness by nine of the twelve pertinent factors: uneven rainfall, a terrain not rough enough to discourage irrigation but rolling enough to require considerable current, light soils, "general-farming" crops (corn, vegetables, berries, pasturage) plentiful surface water, highway and city markets, large average incomes (net cash -- $1,436), wide-awake attitudes, and a low percentage of tenancy. The only definite "low-rate influence" seems to be an apparent slowness in giving electricity widespread utilization (present monthly consumption -- 44 kwh). Seasons are of normal length and a few members have had experience with gas-engine installations which would doubtless be replaced if pumping rates were made attractive. Considering that optimistic picture, potential annual load can be estimated as follows: 233 irrigators -- 23 per cent of membership, 490 kwh per member, 119 kwh per irrigator, 114,170 kwh total.

(4) Located in a less important group of humid-region projects is Washington-25-Cowlitz, rather representative of supplemental irrigation potentialities in the "West-of-the-Cascades" area.

A relatively heavy load is suggested for this 179-member borrower by the following factors: scanty summer rainfall (twelve or more applications per season would probably be necessary), sandy soils, crops of high water-consumption (alfalfa, kale, cabbage, etc.), numerous streams, progressive attitudes, owner operation (tenancy -- 14%), and familiarity with irrigation practices. Purely negative influence seems to be exercised only by the low average incomes (net cash -- $691) and the lack of electrical experience. The terrain is a mixture of creek-bottom flats and little hills that is neither a great encouragement or discouragement to small-scale crop-watering. Seasons are of normal length and the market -- while nothing outstanding -- is bolstered up by the nearness of Portland. With such influencing variables as those, potential load may approximate the following: 25 irrigators -- 14 per cent of membership 1/, 475 kwh per irrigator, 66 kwh per member, 11,875 kwh total.

b. Sectional Analysis. As indicated by load figures for those representative projects, some states are better adapted to supplemental irrigation development than others. The consumption characteristics of any section will depend, of course, upon the combined results of utilization in individual projects, but there

1/ Small percentage of irrigators is partly result of the large number of lumbering and other non-farm members.

are certain overall tendences which can be mentioned in painting a general picture. These tendencies are based upon the same factors as were used in analyzing project load. In brief preview, it can be said that the order of goodness from the viewpoint of irrigation "selling" by REA is as follows: Mid-west, East, South and Northwest.

(1) In the Mid-west the potential load from crop-watering is high because nearly everyone of the twelve variables exercises some influence in that direction. There are frequent long periods between rainfalls, a terrain neither too flat nor too rough, light soils, and numerous sources from which water can be pumped. Among the indirect considerations are such things as progressive attitudes, generally high incomes, a large urban population, and some degree of familiarity with electricity. With these influences in mind, the following estimates of potential load do not seem unreasonable: 79,072 irrigators — 22.7 per cent of membership, 509 kwh per irrigator, 115 kwh per member, 40,296,017 kwh total.

(2) Though the East contains fewer projects than the Mid-western sector, it has many states in which REA would do well to promote supplemental irrigation. Markets are very large, numerous, and near to the projects. There is much truck growing for the large metropolitan areas and for roadwise stands. Some of the soils and terrains are not too well adapted to artificial crop

watering, but these drawbacks are not serious. Potential pumping load, therefore, might be as follows: 11,443 irrigators — 21.4 per cent of membership, 494 kwh per irrigator, 107 kwh per member, 5,657,469 kwh total.

(3) Because incomes are low, rainfall plentiful, altitudes conservative, etc., the South will not be likely to take on supplemental irrigation so widely as other sections. Because of the large number of projects, however, total load will be high and is worth going after. Also, there are such favorable influences as the long season, the numerous sections — like Florida — where intensive truck growing is carried on, and the plentiful water available for pumping. Potential load: 33,708 irrigators — 16 per cent of membership, 434 kwh per irrigator, 72 kwh per member, 14,641,320 kwh total.

(4) If the humid regions of the Northwest contained more projects, this section might rank higher as a field for supplemental watering development by REA. The growing seasons are very dry and irrigation increases yields phenomenally. Incomes are fairly high, there is considerable experience with gas engine installations, and attitudes are very forward looking. Total potential yearly load is only 11,875 kwh and — because many members are not farmers — the consumption per member is only 66 kwh, but the other figures are more revealing: 465 kwh per irrigator for the 625 cooperators likely to install systems.

c. Analyses Tabulated. In order that REA might have ideas of potential load for particular states, estimates have been made for the thirty-three states in which supplemental irrigation would be feasible. These are based, primarily, are materials of C.R.E.A., Robey, Staebner and Horton:

Potential Supplemental Irrigation Load
Per Season For REA Borrowers[1]

Section	Total kwh consumption	Likely number of irrigators	Average kwh per irrigator	Average kwh per member	Likely load of typical project (800 members)
1. The East:	5,657,469	11,443	494	107	84,800
Conn....	24,750	55	450	108	86,400
Del.....	675,400	1,227	550	206	164,800
Maine...	47,850	87	550	124	99,200
Md.(w)..	105,420	251	420	79	63,200
a. N.J.....	210,450	366	575	142	113,600
N. Y.(x)	431,775	909	475	71	56,800
Pa.......	2,050,730	3,982	515	116	92,800
Vt.......	39,150	87	450	84	67,200
Va.......	1,985,684	4,252	467	94	75,200
W.Va....	86,260	227	380	57	44,800
b. Pa.-17-Armstrong(y)	66,450	150	443	91	—
2. The South:	14,641,320	33,708	434	72	57,600
Ala......	1,050,000	2,500	420	57	45,600
Ark......	828,000	2,300	360	46	36,800
Fla......	735,930	1,258	585	145	116,000
Ga.......	3,808,400	9,775	390	73	58,400
a. La.......	575,920	1,694	340	51	40,800
Miss....	1,301,810	3,886	335	50	40,000
N.C.....	1,879,200	4,176	450	84	67,200
S.C.....	824,190	1,986	415	68	54,400
Tenn....	3,637,830	7,133	510	97	77,600

1 Estimates are based on allotment figures, as of June 1, 1939. Thus, the full potential load suggested probably could not be realized until all allotments of that date have reached energization.

Potential Supplemental Irrigation Load
Per Season For REA Borrowers[1/]

Section	Total kwh consumption	Likely number of irrigators	Average kwh per irrigator	Average kwh per member	Likely load of typical project (800 members)
b.Ga.-67-Bacon(y)	46,250	125	370	47	—
3.The Mid-west...	40,265,017	79,072	509	115	92,000
Ill.......	5,633,600	11,200	503	151	120,800
Ind.......	7,042,000	14,000	503	137	109,600
Io........	5,038,200	9,330	540	142	113,600
Ky........	1,161,065	3,181	365	40	[illegible],000
Mich......	4,238,300	7,706	550	124	99,200
Minn......	3,891,300	7,630	510	105	84,000
a.Mo........	2,274,030	4,594	495	74	59,200
Neb.(z)..	1,206,150	2,365	510	63	50,400
N.D.(z)..	369,396	993	372	177	141,600
Ohio......	5,536,000	10,485	528	131	104,800
S.D.(z)..	169,680	336	505	146	116,800
Wisc......	3,489,456	6,672	523	118	94,400
b.Ind-24-Carroll(y)	114,170	233	490	119	—
4.The North-west....	290,625	625	465	60	48,000
a. Oregon(z)	107,880	232	465	64	51,200
Wash.(z).	182,745	393	465	57	45,600
b.Wash.-25-Cowlitz(y)	11,875	25	475	66	—
5.The Whole country.	60,649,066	123,636	491	99	79,200

(w) If projects were in "truck" regions, potential irrigation load would be much higher.
(x) No "cooperative" projects. Irrigation load available to N.Y.Gas and Electric Corporation, the only borrowers.
(y) See discussion above.
(z) Includes only projects in humid portions of these states.

IV. OPTIMUM CONDITIONS

Despite the many potential benefits from supplemental irrigation, however, it is only advisable — as was hinted in the last chapter — when certain conditions, besides rainfall inadequacy, are in evidence. The water supply should be sufficient to completely cover the irrigated acreage about every ten days. The soil and terrain should be well adapted to supplemental water. Moreover, the crops grown should be varieties which have proven successful under irrigation.

Since the presence or absence of these conditions varies from farm to farm, the decision as to advisability must be made on an individual basis. If the decision is made correctly, the increased income from supplemental irrigation in almost every season should more than cover charges for labor, operation and overhead. It should be noted, however, that this practice will not succeed even in the most ideal situation, unless the irrigator uses his installation wisely and complements it with generally sound cultivational and business techniques.

A. PROPER WATER SUPPLY AVAILABLE

The first essential of advisable supplemental irrigation is a plentiful, reliable and conveniently located water supply.

Satisfactory supplemental irrigation requires a surprisingly heavy amount of water. The average irrigated plot should be blanketed with an inch-depth of water about every ten days during the hot part of the growing season. This means that there must be at least 27,000 gallons of water (an acre-inch) available for each acre at each irrigation or — figuring nine irrigations per summer — about 243,000 gallons per acre per season. Most irrigation experts, however, say that these figures should be doubled, because of losses in conveyance and distribution, to 54,000 gallons per irrigation and 486,000 gallons per season.

Reliability of water supply is an important consideration. The heaviest demands of a supplemental irrigation installation must be fulfilled during the driest part of the summer. Stream and well records should be carefully surveyed for height of flow in dry spells before any irrigation investment is made. This survey is especially necessary in Western Nebraska, South Dakota and other states along the Western edge of the humid zone.

Location plays a part in determining a water supply's suitability for supplemental irrigation. Piping and pumping, necessary elements in conveying water from the lake, river, or other source to irrigation plot — are expensive features, whose expense varies directly with the distance and elevation to be covered. Generally speaking, a conveyor line of over 1,500 feet is financially unfeasible

unless gravity can be utilized.

Even the quality of water available has some bearing on the success of supplemental irrigation. Swamps, bogs, and too heavily concentrated sewage are not good sources. Water from warm, particle-filled streams, however, is exceptionally beneficial because it has some degree of fertilizing, as well as irrigating, value.

There are various water sources which can satisfy the requirements mentioned above. In general these can be classified under the following heads: flowing streams, wells, still-water, other sources.

The flowing streams are very satisfactory if they have sufficient volume and do not go dry in mid-summer. They provide an inexpensive source which does not involve a high vertical lift and sometimes even makes possible gravity conveyance. Springs, small creeks, and large rivers are included in the category.

Supplemental irrigation water can be provided by wells of varying capacities, providing the depth does not necessitate too great expenditure for a high-head pump and high-power motor. Large-capacity wells need be pumped only as applications to the land are necessary. Medium-capacity wells have to be pumped 24 hours a day during the irrigation season, with water being stored in intervals

between actual irrigations. Small-capacity wells can be used if they are pumped continuously during the spring and summer, with storage being accomplished in small individual farm ponds.

These small individual farm ponds, of course, are also a still-water source of irrigation water. Rough but satisfactory dams, according to drainage engineer F. L. Staebner can be constructed in a week's time, using tractors and the regular farm help. Such dams are usually placed in gulleys and narrow ravines where they can store either spring run-off or the flow of small brooks. Incidentally ponds of this nature represent a contribution to soil conservation as well as supplemental irrigation. The other still-water resources are lakes and an occasional water pit made by excavation below the water table.

Miscellaneous water supplies used for supplemental irrigation include city-water mains and city sewerage. REA irrigators, moreover, might very well be able to integrate their irrigation system with their already-installed house and barn plumbing systems.

B. PROPER SOIL AND TERRAIN

The second condition necessary before humid-area irrigation is advisable, is a soil and terrain well adapted to supplemental water. Such is the case, according to a News Letter of the Illinois State Horticultural Society, when the water-holding capacity is neither very high nor very low, the land is not hilly but does provide drainage, the substratum is relatively impervious and about sixteen inches below the surface.

Sandy loams give excellent results under irrigation as do most of the lighter soils. Fine-textured clays and loams sometimes cake when supplemental water is applied.

Hilly land is undesirable from the farmer's viewpoint since it makes impossible certain inexpensive methods of irrigation as well as making more expensive those which can be used. The rough terrain develops a high head and consequently necessitates bigger pumps, bigger motors, and more energy. A slow even slope, incidentally, is considered desirable.

The impervious substratum is more essential to some methods than others, but means better results no matter what technique is used. If there is no such stratum, the water sinks below the root range before the plants have had a full opportunity to absorb it.

C. PROPER PLANTS GROWN

Supplemental irrigation is <u>advisable</u> only when applied to certain crops, which are grown intensively and are particularly susceptible to moisture conditions. Truck crops — especially spinach, radishes, tomatoes, beets — are in this category, as are various small fruits, like strawberries, logan-berries, etc. Citrus and orchard fruits also respond well to irrigation. Potatoes and beans are cash crops giving particularly large returns under proper supplemental water.

Irrigation has also been successfully applied in humid areas to pasture and field crops — particularly corn and alfalfa. The investment and acreage involved are so large, however, that these crops are rarely chosen by a grower for his first venture into supplemental watering. This is especially true in the East where the decentralized nature of rural holdings makes thousand dollar cultivational expenditures a decided rarity.

D. INCOME EXCEEDS EXPENDITURE

Most important of all factors in determining the advisability of supplemental irrigation for any particular grower, is the likelihood of the investments "paying out". Increased yields which cost more than they bring in are no boon to the farmer except as the net outgo is payment for crop insurance.

The likelihood of paying out depends on a complex of various factors. The expense of irrigation — determined to some extent by the particular irrigational method which can be employed — is an important consideration. The nearness and steadiness of the demand is another, as is the price level for the crop irrigated. The wisdom with which the irrigator applies his water and markets his larger and better crops also helps decide success or failure. Later on we will cite some statistics

showing the very considerable financial benefits which typical irrigators have received.

V. IRRIGATION METHODS

When a farmer is determining the advisability of supplemental irrigation for his particular crop, one of the important considerations should be the means by which that irrigation might be accomplished. Various situations call for various distributional methods having various advantages and various installation and operation costs. Where one system would be feasible, another might not. In this section, therefore, we will discuss briefly the distinguishing characteristics of each method.

A. OVER-ALL IRRIGATION CHARACTERISTICS

Such a discussion should be preceded, however, by mention of certain features which are common to all irrigation systems. These features have to do with the transferal of the water from its source to the point of distribution among the plants. As such they involve pumps, motors, conveyor pipe, etc.

1. THE TYPE OF PUMP essential to satisfactory irrigation depends on the amount of head which has to be overcome. Generally speaking, centrifugal pumps are preferable because of more regular flow, greater reliability, and more reasonable first cost. Where there are high heads to be overcome the deep well turbine should be used. The amount of head depends on the following factors: suction, vertical lift, friction loss (varying with

length and diameter of pipe), and necessary operating pressure (varying with the distribution method). Within a pump type, as explained in Chapter III, the size depends upon the area to be irrigated, the rapidity with which irrigation is desired, the distribution method used. In other words the necessary gallon per minute capacity is the measure to determine the pump size. The table below was prepared by Robey to show necessary capacities under varying conditions:

<u>Size of Pump Required for Applying One Inch of Irrigation Water on Various Areas</u>

Size of Area in Acres	Rate of Application — Hours									
	1	2	3	4	5	6	7	8	9	10
	Gallons per minute									
0.1.......	50	25	16.6	12.5	10	8.7	7.1	6.2	5.5	5
0.2.......	100	50	33.3	25	20	16.6	14.2	12.5	11	10
0.3.......	150	75	50	37.5	30	25	21.4	18.7	16.6	15
0.4.......	200	100	66.6	50	40	33.3	28.5	25	22	20
0.5.......	250	125	83.3	62.5	50	41.6	35.7	31	27.7	25
0.6.......	300	150	100	75	60	50	42.8	37.5	33.3	30
0.7.......	350	175	116.6	87.5	70	58.3	50	43.7	38.8	35
0.8.......	400	200	133.3	100	80	66.6	57	50	44.4	40
0.9.......	450	225	150	112.5	90	75	64	56	50	45
1.......	500	250	166	125	100	83	71	62	55	50
2.......	1,000	500	333	250	200	166	142	125	110	100
3.......	1,500	750	500	375	300	250	214	187	166	150
4.......	2,000	1,000	666	500	400	333	285	250	220	200
5.......	2,500	1,250	833	625	500	416	357	310	277	250
6.......	3,000	1,500	1,000	750	600	500	428	375	333	300
7.......	3,500	1,750	1,666	875	700	583	500	437	388	350
8.......	4,000	2,000	1,333	1,000	800	666	570	500	444	400
9.......	4,500	2,350	1,500	1,125	900	750	640	560	500	450

2. THE MOTIVE POWER for irrigation pumping may be furnished by either a gasoline or electric motor. The horsepower required depends on the necessary gallons per minute and the head which has to be overcome. In other words, the selection of a satisfactory motor involves consideration of the same factors as does selection of a satisfactory pump. Indeed, a correctly-chosen pump will not give the desired results unless it is complemented by a correctly-chosen motor.

2. PIPING FROM WATER SOURCE to distribution plot is an expensive element in irrigation installation. Metal pipe is recommended but occasionally heavy canvas hose can be used. Because of friction loss, the size of pipe influences the amount of head and therefore the choice of pump and motor. The general rule is that pipe diameter should vary directly with the distance to be piped and the gallons per minute necessary for satisfactory irrigation. Thus a two inch pipe is recommended for conveying 40 gallons per minute 600 feet, 3 inch pipe 100 gallons per minute 1,000 feet. An attempt to economize by buying too small pipe is counteracted by the necessity of using more energy.

B. SUBSURFACE IRRIGATION

Distributing water after it gets to the crop area — and it is in the distribution, as explained before, that supplemental irrigation techniques vary — may be done by the subsurface method.

[illegible]

[illegible] of friction loss, the size of pipe influences the amount of head and therefore the choice of pump and motor. The general rule [illegible]

[illegible]

[illegible]

Porous tiles are laid approximately 18 inches below the top soil and water gradually percolates up from them to the root structure. The method is much used in Florida for citrus growing, but otherwise it is quite uncommon.

Subirrigation is only successful where several special conditions exist. The top soil has to be underlain — as is the case in Florida — by an impervious substratum which will prevent the water from going down instead of up. Moreover, a sandy soil is almost an essential, as is a level or slowly sloping terrain. Besides those limitations, the method is also quite expensive and hence can only be applied to high-priced, intensive crops.

C. SPRAY IRRIGATION

Probably the best and most expensive methods of distributing supplemental water come under the general heading of spray irrigation. The distinguishing characteristic of these methods is that they use pressure to send jets of water upon the plants to be irrigated. They have the common advantage of adaptability to almost any terrain and any soil.

1. OVERHEAD SPRINKLER PIPE IRRIGATION, as developed by the Skinner Company of Troy, Ohio, is probably the best known method of Eastern irrigation. It has been used successfully by truck gardeners for thirty years, and is probably not excelled by

any other method for very high-priced intensive crops grown on small acreage. The installation cost is very high but the operation cost is exceedingly low.

According to claims put forward by the Skinner Company, this system satisfied all the principles of sound irrigation. By slow, spray-like distribution at the rate of an acre-inch in seven hours, it leaves the ground "unpuddled" and uncaked. The unhurried and unexcessive application also enables the soil to absorb the water without becoming "cold". Because the irrigation comes as a gentle mist, plants are not bruised or chilled. Considerable frost protection is possible with this system, as is excellent uniformity of distribution. With it a grower has complete control over the amount and time of irrigation. Such claims as these are not over-estimation, but it should be noted that other methods also have certain of those capabilities.

The system, as described by J. P. Schoenzer in "Agricultural Engineering" consists of elevated pipe lines supported as posts 1½ to 6 feet in height, and about fifty feet apart. The pipe is drilled and topped for a fine-bore brass nozzle every 3 or 4 feet. When water is pumped into it at 40-pounds or more pressure, tiny streams of water come from the nozzles which are perpendicular to the pipe and parallel to each other. The pipe can be turned so as to irrigate first one side of it and then the other. Approximately

870 feet of pipe are required to water an acre.

Some growers use portable equipment. This reduces the installation cost, but increases the labor required in moving the nozzle lines from field to field. The pipe may be laid upon the ground, low posts, or special devices. It does have the advantage of being out of the way for field work. Because of the constant moving, portable installations will not have the length of life of equipment installed permanently.

2. REVOLVING SPRINKLER IRRIGATION is another very satisfactory method of spray irrigation. If a portable system is selection — as is now possible with the development of flexible joint pipes — the installation costs are lower than for the overhead systemand the operating costs not much higher. It, too, can be used on rolling topography and for frost protection, though not quite so effectively as the Skinner method. Like the Skinner, also its slow application gives adequate irrigation without erosion and caking. The system seems particularly well adapted for small kitchen-garden units.

The layout now usually consists of a semi-permanent main feeder line with portable, light-weight laterals. These laterals are moved from place to place as the water is applied to the land. The pipe used for the laterals is of light weight and comes in 20 foot lengths.

Double-nozzle sprinkler heads have been developed. One of these covers the outer area of the circle while the other irrigates the inner section. "A discharge of 15 to 20 gallons per minute and covering a diameter of 90 feet at 40 pounds pressure, is common practice," says Schoenzer. One revolution or less per minute is a desirable speed for the sprinkler.

3. PERFORATED PIPE IRRIGATION is a new development in the spray irrigation category. Its chief advantage is the low operating pressure necessary; this ranges from 2 to 6 pounds. The method is best adapted to row crops. It cannot be used for frost protection and probably is somewhat less uniform in application than the other spray systems. The installation lasts long and is moderately priced.

The method consists of 4- or 5-inch flexible joint pipe with small staggered perforations along its length. The pipe moved from row to row as the irrigation progresses, the labor involved not being extremely tedious. "Eyelet hose" is a canvas version of this method.

D. SURFACE IRRIGATION

So-called "surface" methods of applying supplemental water are characterized by direct distribution to the top-soil without benefit of any devices converting the water into a down-pouring of fine

spray. Included in this category are some of the most primitive and least expensive systems of irrigation. Most of the methods are associated with large-scale Western watering but they can sometimes be applied to Eastern irrigation as well. All of them require, however, that the irrigated area be smooth and either level or slightly sloping.

There are various drawbacks to these methods. The necessary leveling may prove costly, in addition to exposing unproductive sub-soil. There is a tendency towards puddling, caking and uneven distribution. The systems are very uneconomical with water; the land is usually over-watered, much evaporation loss occurs, there may be considerable leakage, etc. Despite these disadvantages, however, the method is a decided benefit to various "mass-production" crops not intensively enough cultivated to justify the more expensive techniques.

1. THE FURROW METHOD is used a great deal in connection with the production of row crops. Field furrow between the crop rows carry the water which is supplied by the conveyor system from head ditches, or gated, low-pressure, light weight, portable surface pipe or other similar means. To secure the most uniform results, the slope of each furrow should be such and the quantity of water entering it such an amount as to reach the lower end as quickly as possible. The slope should not be so steep, however, as to cause erosion.

2. THE FLOODING AND CHECK METHODS of irrigation consist of permitting water taken from a distribution ditch or feeder pipe to flow over the land. Naturally, the level of the water in the ditch must be higher than the land and must be located at the highest point in the field. The area is divided into checks and basins which are opened to a certain amount of water and then closed. Careful leveling and considerable labor are necessary.

3. THE BORDER METHOD of irrigation involves layout parallel strips of land extending down the slope of the area. Each strip is demarcated by borders between which the irrigation water flows. Widths of 25 feet and lengths of not above 300 feet are recommended for sandy loams. The water is regulated as for the furrow and flooding systems.

E. POROUS HOSE IRRIGATION

The distinguishing feature of another method of irrigation — developed chiefly in Michigan — is the use of canvas to convey and distribute water. One end of the hose is attached to the water supply line while the other end is closed. As the water is pumped into the hose and fills it, the 15-to-20 pound internal pressure causes it to ooze slowly through the walls. Various devices are used in moving the hose from row to row. The method is very well adapted to kitchen gardens.

[illegible] that it flows over the land. Generally, the level of the water in the tank must be higher than the land and must be located at the highest point on the field. [illegible]

3. THE BORDER METHOD of irrigation involves long parallel strips of land extending down the slope of the area. Each strip is demarcated by borders between which the irrigation water flows. Widths of 25 feet and lengths of not above 300 feet are recommended for sandy loams. The water is maintained as for the furrow and flooding systems.

4. [illegible]

The [illegible] — developed chiefly in Michigan — is the use of canvas to convey and distribute water. One end of the hose is attached to the water supply line while the other end is closed. As the water is pumped into the hose and fills it, the 15-to-60 pound [illegible] moving the hose from row to row. The [illegible] kitchen gardens.

The system has several important advantages which lead R. L. Horton to predict its widespread acceptance in the East. The slow application means no erosion and also hinders puddling and caking. The direct-to-soil application keeps leaves dry and thus makes impossible the harm which sprinkling is supposed to do some plants. It is a system, moreover, which can be used over rough ground having elevations up to three feet. The installation cost is very low and the method is extremely flexible.

There are several disadvantages which partially counteract the benefits mentioned in the last paragraph. Much labor is involved in moving the hose and considerable care must be taken to see that no tender plants are harmed in this process. The depreciation charges are quite high since the canvas has a usual maximum life of three years. The rate of application is almost too slow for large installations.

[illegible]
of [illegible]
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[illegible]

VI. F I N A N C I A L   C O N S I D E R A T I O N S

Amidst the multitude of cost and income statements which humid-area irrigators have compiled, the one fact which stands out clearly is that ninety per cent of the installations have paid out in a remarkably short time. Almost always supplemental irrigation has been something more than a mere negative insurance. Beyond that central point, however, there is much conflicting and disorganized testimony as to detail.

The absence of a clear, complete, consistent presentation of supplemental irrigation's financial aspects is chiefly due to the great variability in those aspects. Every method has a different installation cost and operating charge. Some farmers already have part of their equipment; others do not. The size of the area to be irrigated has considerable influence upon the per-acre installation cost. The dryness of the season decides the frequency of necessary irrigation and hence, influences the operating charges.

It is possible, however, to make rough estimates of the likely cost of irrigating a given area with various methods under fairly typical conditions. In this section, therefore,

VI. [illegible]

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It is possible, however, to make rough estimates of the [illegible]

we will set forth the approximate expenditures involved in irrigating a three-acre plot 750 feet from the water supply; such an installation might be considered a typical size for humid-area irrigators using supplemental water on income-producing crops. The per-acre figures arrived at — based as they are on rough averages of data supplied by Bobey, Stoebner, various Oregon investigators, a C.R.S.A. report, and several other experimenters — may be considered quite representative for installations of an acre and up. Kitchen gardens and other small areas call for different approximations.

In evaluating these estimates, the reader should keep several points in mind. Labor charges have been included at the rate of $.30 per hour; it is often the case, however, that a considerable amount of work connected with irrigation can be done by the irrigator himself in time which might otherwise be used less productively. Probable costs for everything from well-digging to conveyor pipe have been included but it is very likely that a farmer considering irrigation would already possess some of the necessary equipment. Moreover, it is also probable that such equipment — even if it is bought primarily for irrigation — can be used for other farm purposes, thus giving good ground for charging part of expenditure and depreciation against some other use.

[illegible] will not prove too expensive [illegible]

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such an installation might be considered a typical size for

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[illegible]

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In considering these estimates, [illegible]

several points in mind. Labor charges have been included at the

rate of $.20 per hour; it is often the case, however, that a

[illegible]

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be used less productively. Probable costs for everything from

well-digging to conveyor pipe have been included but it is very

[illegible]

[illegible]

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gation — can be used for other farm purposes, thus giving good

ground for charging part of expenditure and depreciation against

such other use.

A. INSTALLATION COSTS

A three-acre plot 750 feet from the stream requires a system of water conveyance — pump, motor, main pipe-line, etc. — and a method of distribution. As discussed before, the conveyance system — at least on a plot of that size — will be approximately the same regardless of what distribution is called for by peculiarities of terrain, soil and crop raised. Therefore, we will give estimates for "conveyance" cost first and follow them with data concerning various distribution techniques. Note the following table:

1. Cost of Getting Water to Distribution Point

Items	Cost, 3-acre	Cost per acre	Remarks
1. Small Dam (Including labor, tractor, fuel, engineering advise, etc.	$ 50.00	$ 16.66	Usually not necessary. May have soil conservation worth and provide water for cattle. Part of expense might well be charged against those uses.
2. Well (Digging moderately deep well or series of shallow ones)	$125.00	$ 41.66	Last resort when no other supply available. Generally too expensive for Eastern irrigation
3. Pump (Usually centrifugal)	$ 75.00	$ 25.00	Piston pumps sometimes used on smaller installations
4. Motor (3 hp. gas or electric)	$ 75.00	$ 25.00	One half of expense might well be charged against other uses
5. Conveyor Pipe (3" metal at 18¢ per foot)	$135.00	$ 45.00	Many units have to carry water less than 750 feet
6. Miscellaneous Fixtures (elbows, screens, etc.)	$ 18.00	$ 6.00	Sometimes farm odds-and-ends can be used for 1/3 of expenditure

[illegible]

A. [illegible]

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[illegible]

Remarks	Cost per acre	Total cost	Item
[illegible] save soil conservation work and provide water for cattle. Part of expense might well be [illegible]	$ [illegible]	[illegible]	1. [illegible] Dam ([illegible]) [illegible]
Last resort when no other supply available. Generally [illegible] irrigation	$ 41.[illegible]	[illegible]	2. [illegible] well [illegible]
[illegible] on small or intensive [illegible]	$ [illegible]	[illegible]	3. [illegible] ([illegible]) 75.00
One half of expense might well be charged against other uses	$ [illegible]	[illegible]	4. [illegible]
[illegible] unless have to carry [illegible]	$ [illegible]	[illegible]	5. Conveyor Pipe (3" metal [illegible])
[illegible] can be used for 1/3 of ex[illegible]	$ [illegible]	[illegible]	6. [illegible]

1. Cost of Getting Water to Distribtion Point

Items	Cost, 3-acre	Cost per acre	Remarks
7. Installation Labor (@30¢ per hour)................	$ 6.00	$ 2.00	Farmers do much of this themselves and do not count it regular expenditure
TOTALS — CONVEYANCE INSTALLATION			
1. Maximum, Water Supply Available................	$309.00	$103.00	Quite common. Expenditure advisable on good irrigation crops
2. Maximum, Dam Built.........	$359.00	$119.67	Feasible when high priced crops grown or dam has marked soil conservation value
3. Maximum, Well Dug.........	$434.00	$144.67	Rarely feasible except on large installations and high priced cash crop
4. Probable Minimum (Free water, motor already possessed, labor not counted, 1/3 off on miscellaneous fixtures)..................	$222.00	$ 74.00	Feasible for pasture irrigation, alfalfa, corn and other low-priced crops
5. Most Likely (Free water, 1/2 labor counted, 1/3 off on miscellaneous fixtures)................	$262.50	$ 87.50	Advisable for irrigation of all good irrigation crops, including alfalfa

Several clarifying remarks might be made before we pass on to the other element of installation costs: 1. Because acreage changes do not cause proportionate changes in equipment expenditures, the cost per acre tends to decrease as the installation becomes larger and to

increase as it becomes smaller. 2. Totals for "conveyance" installation costs under different combinations than presented, can easily be worked out from the above table 3. The approximations are more likely to be over than under-estimates.

2. Distribution System Costs and Total Installation Expenditures

Method	Cost of distribution equipment per acre	Labor used installing distribution equipment, per acre	Total distribution installation cost per acre	Most likely total installation cost per acre	Remarks
1. Sub-irrigation..........	$140.00	$ 10.00	$150.00	$237.50	Labor cost high in burying tiles. Cannot be done by irrigator himself. For correct soil condition and high-priced, readily-sold crop
2. Furrow........	$ 5.00	$ 2.10	$ 7.10	$ 93.55	Little equipment but wooden sluices and gates. Little labor needed. Hardy plants and gradual slope. At least 1/2 labor can be done by farmer himself
3. Border........	$ 3.00	$ 2.60	$ 5.60	$ 91.60	Hardly any equipment needed. Considerable labor necessary to make borders but at least 1/2 can be done by farmer himself. Gradual slope, hardy pl...

2. Distribution System Costs and Total Installation Expenditures

Method	Cost of distribution equipment per acre	Labor used installing distribution equipment, per acre	Total distribution installation cost per acre	Most likely total installation cost, per acre	Remarks
4. Flood and check..........	$ 3.00	$ 2.30	$ 5.30	$ 91.65	Hardly any equipment needed. Some labor used in outlining check plots but at least 1/2 can be done by irrigator himself. Gradual slope, etc.
5. Permanent overhead.......	$295.00	$ 3.50	$298.50	$384.25	Considerable labor involved in setting poles, raising line, etc Adapted to most soil and terrain, but must have intensive crop. About 1/2 labor done by farmer
6. Portable overhead.......	$168.00	$ 2.00	$170.00	$256.50	Less labor involved because permanent line setting is not a part of job. At least half labor could be done by farmer himself. More operating labor needed
7. Revolving sprinklers.....	$ 73.00	$ 1.80	$ 74.80	$161.40	Not much labor involved in laying main feeder line if surface variety used. Other labor is of operating nature. At least 1/2 labor and be done by farmer himself.

2. Distribution System Costs and Total Installation Expenditures

Method	Cost of distribution equipment per acre	Labor used installing distribution equipment, per acre	Total distribution installation cost per acre	Most likely total installation cost, per acre	Remarks
8.Perforated pipe..	$ 50.00	$ .50	$ 50.50	$137.50	Practically all labor is of operating nature. What labor there is connected with installation can be done entirely by farmer
9.Porous hose.....	$ 5.00	$ .50	$ 5.50	$ 92.50	Practically all labor is of operating nature. Installation can all be done by farmer

The worth of that table, too, may be enhanced by several explanatory remarks: 1. In reckoning "most likely total installation cost per acre", the labor cost has been included as one-half the total used, i.e., only the actual payout for labor is considered as an element of total installation expenditure; there are exceptions for sub-irrigation where all labor is added — because the large amount of it necessitates much hired help— and for perforated pipe and porous where no labor is added — because the small amount of it can be entirely accomplished by the farmer himself. 2. The size of the

installation costs indicates that certain types of supplemental irrigation for "larger-than-an-acre" plots can only be available to the average farmer if some reasonable financing method is provided. 3. The size of installation costs indicates, also, that irrigation for the farm budget is a major business transaction; to succeed — in most cases — it must be applied to high-priced "truck", berries or certain lower-priced products, like potatoes, that are phenomenally benefited by supplemental water. 4. The "most likely" conveyance installation cost has been used as the basis for estimating "most likely total installation" expenditures with different systems; costs under different "conveyance-installation" conditions can be worked out by referring to the prior table. 5. Once again the error is more likely to be on the side of overestimation.

That our "average-and-judgment" estimates are probably not very far wrong is indicated by comparison with several of the most respected studies in the field. For instance, the average installation cost of 2021.75 acres of permanent overhead irrigation in New Jersey was $377.31 per acre (our estimate — $384.25) according to New Jersey Bulletin #453. In Farmer's Bulletin #1635, F. E. Stoebner suggests that a surface system using sewer pipe "conveyance" is apt to cost about $100 per acre (our estimate — $92 surface systems average). Portable revolving sprinkler irrigation, according to another Stoebner publication, might involve expenditure of about

\$150 per acre on "above-five-acre" installations (our estimate — \$161.40). A C.R.E.A. Bulletin tells of a Florida citrus grower and truck farmer who paid \$350 per acre for a sub-irrigation system (our estimate — \$161.40). A C.R.E.A. Bulletin tells of a Florida citrus grower and truck farmer who paid \$350 per acre for a sub-irrigation system (our estimate — \$337.50).

b. OPERATION CHARGES

After an irrigator has past the initial hurdle of installation costs, the outgo per season is what interests him. Once again there are certain elements of the charge which vary from system to system and others which do not. Since expenditure for "conveyance" equipment is approximately the same no matter what distributional technique is used, the depreciation and maintenance charges for that part of a complete installation are likewise the same no matter what the distributional system. Charges for energy, operating labor, interest, distribution system depreciation and maintenance, on the other hand depend directly upon the particular method applied.

The charts that follow present estimates of probable average operating charges for the various systems on plots larger than an acre. The "most likely 'conveyance' installation costs" and the " 'most likely' total installation costs" have been used as a basis for reckoning depreciation and interest charges in these approximations;

the results obtained should be considered the "most likely operating charges." Depreciation on "conveyance" installation has been reckoned at 10 per cent and maintenance on "conveyance" installation is estimated at $1.80 per acre per year. Interest is figured at 6 per cent; labor at $.30 per hour, energy at .02 per kwh. The acre-inch approximations are worked out on the basis of 9 inch water application per acre per year, an average suggested by both Robey and Horton.

In all cases "total 1" represents the real operating expenses and should be given the most weight in determining whether the annual income from supplemental irrigation justified the annual expenses for it. Totals 2, 3, and 4 represent several "operating cost" concepts which many farmers have. They are based on what is actually paid out in money under various conditions. Few farmers, to illustrate the idea, actually keep a depreciation reserve; few farmers, who have done their own irrigation financing, think of 6 per cent of their net return (interest) as an operating charge; most farmers do not mentally designate part of the irrigation return as wages for their own irrigation work. To them, all returns above payout for energy, maintenance, and hired-help may be "profits".

1. Operating Charges, Sub-Irrigation

Items	Per Acre per year	Per acre-inch	Remarks
1. Labor................	$ .72	$ .08	Very little labor needed to operate. Necessary amount decreases as acreage increases
2. Interest.............	$ 20.25	$ 2.25	Reckoned on $337.50
3. Distribution System Depreciation.........	$ 37.50	$ 4.17	Reckoned on $250 at 15%. Tile deteriorates
4. Distribution System Maintenance..........	$ 3.00	$ .33	Tile tends to deteriorate because of buried dampness
5. "Conveyance" Depreciation.............	$ 8.75	$ .97	Reckoned on $87.50
6. "Conveyance" Maintenance.............	$ 1.80	$ .20	
7. Energy................	$ 5.13	$ .57	Considerable head because of length of pipe and necessity of pressure
TOTALS			
1. Complete.............	$ 77.15	$ 8.17	
2. Without Depreciation..	$ 30.90	$ 3.43	
3. Without Depreciation and Interest.........	$ 10.65	$ 1.18	Too expensive for all but highest-priced crops and
4. Without Depreciation, Interest and 1/2 labor................	$ 10.24	$ 1.14	best soil. Note the smallness, however, of the active charges

2. Operating Charges, Furrow Irrigation

Items	Per Acre per year	Per acre-inch	Remarks
1. Labor................	$ 1.80	$ .20	To prevent over-irrigation, puddling, etc. some provision is needed. Furrows have to be made
2. Interest.............	$ 5.61	$ .62	Reckoned on $93.55
3. Distribution System Depreciation.........	$ 1.07	$ .12	Reckoned on $7.10 @ 15%. Field distribution system of open ditches, sluice ways, etc. deteriorates gradually
4. Distribution System Maintenance..........	$ .45	$ .15	Nearly all maintenance included in labor
5. "Conveyance" Depreciation.............	$ 8.75	$ .97	
6. "Conveyance" Maintenance.............	$ 1.80	$ .20	
7. Energy...............	$ 3.24	$ .36	No distribution pipes or pressure to cause high head
TOTALS			
1. Complete.............	$22.72	$ 2.52	
2. Without Depreciation..	$12.90	$ 1.43	
3. Without Depreciation and Interest.........	$ 7.29	$ .81	Where terrain suited, makes irrigation of lower-priced crops feasible
4. Without Depreciation, Interest and 1/2 Labor................	$ 6.19	$ .69	

3. Operating Charge, Border Irrigation

Items	Per Acre per year	Per acre-inch	Remarks
1. Labor..................	$ 1.20	$ .13	Not much necessary but supervision
2. Interest...............	$ 5.51	$ .61	Reckoned on $91.80
3. Distribution System Depreciation.........	$ .28	$ .03	Reckoned on $5.60 @ 5%. Borders last long time
4. Distribution System Maintenance..........	$ .09	$ .01	Nearly all included in labor
5. "Conveyance" Depreciation.............	$ 8.75	$ .97	
6. "Conveyance" Maintenance.............	$ 1.80	$ .20	
7. Energy..................	$ 3.24	$ .36	Regards this, same condition as furrow
TOTALS			
1. Complete..............	$20.87	$ 2.32	
2. Without Depreciation...	$11.84	$ 1.32	Least expensive of all irrigational methods. O.K. for orchards and handy plants when topography is correct
3. Without Depreciation and Interest..........	$ 6.33	$ .70	
4. Without Depreciation, Interest and 1/2 Labor................	$ 5.73	$ .64	

4. Operating Charges, Flood Irrigation

Items	Per Acre per year	Per acre-inch	Remarks
1. Labor................	$ 1.50	$ .17	Considerable work incidental to opening and shutting check plots, etc.
2. Interest.............	$ 5.50	$ .61	Reckoned on $91.65
3. Distribution System Depreciation.........	$ .53	$ .06	Reckoned on $5.30 @ 10%. Check ridges, ditches, troughs, etc. wear away
4. Distribution System Maintenance..........	$ .18	$ .02	Much included in labor
5. "Conveyance" Depreciation...............	$ 8.75	$ .97	
6. "Conveyance" Maintenance.................	$ 1.80	$ .20	
7. Energy.................	$ 3.24	$ .36	No surface system has high head
TOTALS			
1. Complete...............	$21.50	$ 2.39	
2. Without Depreciation..	$12.22	$ 1.36	Used extensively in cranberry, rice and orchard culture. Not much good for small-scale supplemental irrigation
3. Without Depreciation and Interest.........	$ 6.72	$ .77	
4. Without Depreciation, Interest and 1/2 Labor.................	$ 5.97	$ .66	

5. Operating Charges, Permanent Overhead Irrigation

Items	Per Acre per year	Per Acre-inch	Remarks
1. Labor..................	$ 1.08	$ .12	Very little necessary especially when automatic oscillators used
2. Interest................	$ 23.05	$ 2.56	Reckoned on $384.25
3. "Distribution" Depreciation..............	$ 14.93	$ 1.66	Reckoned on $298.50 @ 5%. Very durable equipment
4. "Distribution" Maintenance..............	$ 1.75	$ .19	Comparatively few repairs necessary
5. "Conveyance" Depreciation..............	$ 8.75	$ .97	
6. "Conveyance" Maintenance..............	$ 1.80	$ .20	
7. Energy..................	$ 5.13	$ .57	40 lbs. pressure in pipe
TOTAL			
1. Complete..............	$ 56.49	$ 6.28	
2. Without Depreciation...	$ 32.81	$ 3.65	Requires high-priced crop for feasibility. Much used in "truck" gardening. Note how powerfully operating charge is influence by high installation fee
3. Without Depreciation and Interest..........	$ 9.76	$ 1.08	
4. Without Depreciation, Interest and 1/2 Labor................	$ 9.22	$ 1.02	

6. Operating Charges, Portable Overhead Irrigation

Items	Per acre per year	Per acre-inch	Remarks
1. Labor	$ 4.50	$ .50	Much necessary in moving lines
2. Interest	$ 15.39	$ 1.71	Reckoned on $256.50
3. "Distribution" Depreciation	$ 13.60	$ 1.51	Reckoned on $170. @ 8%. Continual moving makes less durable
4. "Distribution" Maintenance	$ 2.00	$ .22	Less durability means more repairs
5. "Conveyance" Depreciation	$ 8.75	$ .97	
6. "Conveyance" Maintenance	$ 1.80	$ .20	
7. Energy	$ 5.13	$ .57	Same pressure need as overhead
TOTALS			
1. Complete	$ 51.17	$ 5.69	Financial wisdom of taking this in place permanent seems doubtful except where economy of first cost is an advantage; for instance, as drought insurance
2. Without depreciation	$ 28.82	$ 3.20	
3. With depreciation and interest	$ 13.43	$ 1.49	
4. Without depreciation, interest and 1/2 labor	$ 11.18	$ 1.24	

7. <u>Operating Charges, Portable Revolving Sprinkler Irrigation</u>

Items	Per Acre per year	Per acre-inch	Remarks
1. Labor...............	$ 3.78	$ .42	Considerable work to moving laterals
2. Interest.............	$ 9.68	$ 1.08	Reckoned on $161.40
3. "Distribution Depreciation............	$ 7.48	$ .83	Reckoned on $74.80 @ 10%. Quite durable, considering movability
4. "Distribution" Maintenance............	$ 1.75	$ .19	Moderate amount of repairs
5. "Conveyance" Depreciation............	$ 8.75	$ .97	
6. "Conveyance" Maintenance............	$ 1.80	$ .20	
7. Energy..............	$ 5.13	$ .57	40 lbs. pressure wanted here also
TOTALS			
1. Complete............	$ 38.37	$ 4.26	More reasonable than "overhead system" and almost as well adapted to hilly terrain and non-sandy soil. Feasible expenditure for most irrigation crops
2. Without Depreciation	$ 22.14	$ 2.46	
3. Without Depreciation and Interest.......	$ 12.46	$ 1.38	
4. Without Depreciation, Interest and 1/2 Labor..............	$ 10.57	$ 1.07	

8. Operating Charges, Perforated Pipe

Items	Per Acre per year	Per acre-inch	Remarks
1. Labor...............	$ 5.40	$ .60	Much necessary in moving pipes
2. Interest.............	$ 8.25	$ .92	Reckoned on $137.50
3. "Distribution" Depreciation............	$ 5.05	$ .56	Reckoned on $50.50 @ 10%. Rusting deteriorates
4. "Distribution" Maintenance............	$ 1.00	$ .11	Few "parts" to wear
5. "Conveyance" Depreciation............	$ 8.75	$ .97	
6. "Conveyance" Maintenance............	$ 1.80	$ .20	
7. Energy...............	$ 3.24	$ .36	Low-pressure delivery is feature
TOTALS			
1. Complete............	$ 33.49	$ 3.72	
2. Without Depreciation.	$ 19.69	$ 2.19	Excellent for tall-growing row-crops. Very reasonable to install and operate. Somewhat cumbersome
3. Without Depreciation and Interest.........	$ 11.44	$ 1.27	
4. Without Depreciation, Interest and 1/2 Labor..............	$ 8.74	$ .97	

9. Operating Charges, Porous Hose

Items	Per Acre per year	Per acre-inch	Remarks
1. Labor..................	$ 6.30	$ .70	Hose irrigation is big job
2. Interest...............	$ 5.55	$ .62	Reckoned on $92.50
3. "Distribution" Depreciation..........	$ 1.83	$ .20	Reckoned on $5.50 @ 33 1/3%. Hose rots in three years
4. "Distribution" Maintenance..........	$ .81	$ .09	Repairs in hose do not cost much
5. "Conveyance" Depreciation..........	$ 8.75	$ .97	
6. "Conveyance" Maintenance.............	$ 1.80	$ .20	
7. Energy;...............	$ 3.69	$ .41	Moderate pressure (20 lbs.) required
TOTALS			
1. Complete..............	$ 28.73	$ 3.19	
2. Without Depreciation.	$ 18.15	$ 2.02	Very inexpensive and very efficient. Feasible for any irrigatable crop. Labor connected with drawback
3. Without Depreciation and interest.........	$ 12.60	$ 1.51	
4. Without Depreciation, Interest and 1/2 Labor..............	$ 9.45	$ 1.05	

To get the true significance of those tables, like the others, several modifying considerations should be kept in mind. First, the figures are purely estimates which in some cases — due to lack of specific information — are nothing more than reasoned guesses; a complete cost-analysis comparison of the various techniques — based directly on check-plot investigations by agricultural engineers — is a lacking essential in the field. Secondly, the estimates have purposely been set high so as not to paint an over-optimistic picture; it is possible that many actual installations — certainly those larger or nearer-water than the three-acre, 750-feet-from-water unit upon which these approximations are based — would cost from 1/3 to 1/4 less to operate than these figures indicate.

Another most important consideration — hinted in the last sentence above — arises from two inter-related facts; "conveyance" equipment, and to some extent "distribution" equipment, for larger installations need not be much more expensive than for smaller; interest and depreciation items make up a very large proportion of total operating expenses. Because of these facts, supplemental irrigation is definitely a "decreasing costs" activity with operation charges and decisions as to most reasonable system depending on size of units. On plots up to ten acres the depreciation and interest charges — based, of course, on installation costs — outweigh payments for labor, energy, and maintenance as detriments of total operating expense; because of that condition, initial

[illegible]

[illegible] field. [illegible]

high as not to paint an over-optimistic picture; it is [illegible]

[illegible]

motor unit upon which these approximations are based — cost [illegible]

[illegible]

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tion costs [illegible]
on size of units. On plots up to ten acres the depreciation and
[illegible]
[illegible] payments for labor, energy, and maintenance as [illegible]
[illegible]

expenditure for irrigation on such plots should be a primary factor in deciding what distributional system to use on units larger than ten acres, labor and energy and maintenance tend to assume greater importance in the total operating charge than do depreciation and interest; for that reason, on such large plots the systems with low active operating expenses — those which require little labor, for example — tend to become more desirable even though the initial costs may be heavy.

Despite those modifications, however, the estimates make plain at least two points. First, they show quite accurately the relative expense of the several supplemental irrigation techniques. Second, they lend emphasis to previous statements that supplemental irrigation as a business practice is generally adopted only to high-priced crops grown for a large, readily-accessible market; though the records show that the practice does pay, it does not cost an insignificant amount.

Like our installation-cost estimates, these "average-and-judgment" figures for operating charges stand up fairly well when compared with the results of several rather complete investigations. O. E. Robey's statistics concerning a ten-acre potato patch irrigated by porous hose — correction being made for interest, depreciation, and maintenance rates used in our approximations — indicate $2.04 per acre-inch as the operating charge.

The C.R.E.A. Bulletin estimates "a total irrigation cost (operating) of $35 per acre" per year for surface methods; with nine applications per season this would mean $3.89 per acre-inch. The same source says "a conservative figure for the total operating cost of spray irrigation is $50 per acre per season." With depreciation and maintenance charges added to his figures, a Florida truck farmer reports sub-irrigation operating expenses per year as approximately $75. F.E.Staebner tells of another eastern truck grower who was able to deliver one-inch applications[1/] for $3.00 per acre with the revolving sprinkler method.

C. INSTALLING AND OPERATING SMALL UNIT

The figures above, you will recall, refer to systems of one acre or more; for smaller units the expenditures should be considerably lower. Installation costs are less because long pipe lines are unfeasible and because most irrigators already possess equipment which can be used in small units. Operating charges are lower because — heads being smaller — less energy (fuel oil or electricity) is consumed and because — installation

1/ In comparing these figures with ours, incidentally, there is at least one other "grain of salt" which should be considered besides varying terrains, plot sizes, distances from water, etc. This additional factor is that varying actual amounts of water are required — because of waste in leakage, evaporation, spreading, etc. — to give an effective one-inch application. In our estimates, which refer to inches of effective water, allowance is made for this wastage. In the cited figures, different allowances are apt to be made; Staebner, for example, says that two inches of water are necessary for each effective one-inch application.

costs being smaller — depreciation and interest items are not so large. This section presents "average-and-judgment" estimates for the small plots in manner similar to that used for the "bigger-than-an-acre" installations.

1. THE TOTAL INSTALLATION COST as explained in Section B, of any supplemental irrigation method is the sum of expenditures for two "constants", conveyance equipment and installation labor, and one available, distribution system. The following tables and comments aim to show how those same factors and relationships operate in determining probable installation costs on various small-plots units.

A. Cost of "Conveyance" Equipment — Small Plots

Items	1-acre	1/2-acre	1/4-acre	Remarks
1. Pump (horizontal centrifugal;2" and smaller;when obtained can be used for other purpose against which part of cost has been charged)	$ 35.00	$ 25.00	$ 20.00	Majority of farms not likely to have; those with farm plumbing systems do
2. Motor (2 horsepower and smaller;electric or gasoline;when obtained can be used for other purposes against which part of cost has been charged	$ 55.00	$ 40.00	$ 30.00	Many farms do have, including those with farm plumbing
3. Conveyor Pipe (1½", 1¼" and 1" respectively;reckoned on 100' as upper limit of feasibility with small plots)	$ 14.00	$ 12.00	$ 9.00	Most farms do not have; some have usable odds and ends which might cut cost by 1/3

Items	1-acre	1/2-acre	1/4-acre	Remarks
4. Miscellaneous Fittings (Intake hose and screen; joints, etc.)	$[illegible].00	$ 9.00	$ 7.00	Most farms have some usable odds and ends which can cut cost by 1/3
5. Installation Labor ($.50 per hour)	$ 2.00	$ 1.10	$ .60	On plots of this size, a good share of installation labor is done by farmer himself
6. Totals "Conveyance" Equipment				
1. All Expenditures Necessary............	$118.00	$ 87.10	$ 66.60	Rarely advisable to irrigate when this is case. Exceptions — very intensive crops grown
2. Most Probable Necessary Expenditures (Motor and 1/3 fittings already possessed; 1/2 labor not counted)	$ 58.00	$ 43.55	$ 33.96	Irrigation profitable on most vegetable crops
3. Probable Expenditures if Plumbing Already Installed (Motor pump and 1/3 fittings possessed; 3/4 labor not counted)	$ 22.50	$ 18.27	$ 13.81	Irrigation very profitable
4. Probable Minimum Expenditures (Motor, Pump, 1/3 Pipe and 1/3 fittings already possessed. No labor counted)	$ 17.24	$ 14.00	$ 10.66	Irrigation very profitable

Several comments upon that table may bring out points which might otherwise be overlooked: 1. There has purposely been no mention made of dam or well-building because such expenditures — unless primarily

directed at something besides irrigation — would be absolutely too great financial burdens for one-acre plots. 2. Small-scale garden irrigation is actually more expensive per acre when a farmer happens to have no equipment at all on hand. 3. Within the one-acre category, the smaller the area irrigated, the greater becomes the cost in terms of one-acre units; this is so, of course, because reductions in acreage do not mean a proportionate reduction in expenditure for necessary equipment. Observe the following table:

b. <u>"Distribution" Costs and Total Installation Expenditure — Small Plots</u>

Methods	Installing Distribution Equipment			Most Like Total Installation Cost			Remarks
	1-acre	1/2-acre	1/4-acre	1-acre	1/2-acre	1/4-acre	
1. Subirrigation.....	$ 250.00	$130.00	$ 68.00	$307.00	$17[illegible].00	$101.66	Most of labor must be hired. Not usually feasible unless terrain "perfect" and very high priced crop
2. Furrow.....	$ 5.50	$ 3.00	$ 1.75	$ 63.50	$ 46.55	$ 35.21	Little hired labor necessary. Decreasing size brings nearly proportionate expenditure decrease. Good for hardy plants
3. Border.....	$ 4.00	$ 2.00	$ 1.00	$ 62.00	$ 45.55	$ 34.96	Not practicable for small plots. Some hired labor necessary

Methods	Installing Distribution Equipment			Most Like Total Installation Cost			Remarks
	1-acre	1/2-acre	1/4-acre	1-acre	1/2-acre	1/4-acre	
4.Floor and Check.....	$ 3.90	$ 1.90	$ .95	$ 41.90	$ 45.45	$ 34.91	Not practicable for small plots Some hired labor necessary
5.Permanent Overhead..	$300.00	$160.00	$ 85.00	$358.00	$ 205.55	$118.96	Too expensive for most small plots unless very high priced product is much improved by irrigation
6.Portable Overhead..	$170.00	$ 85.00	$ 42.50	$228.00	$ 128.55	$ 76.46	Practically all labor can be done by farmer. O.K.for "truck vegetable" specialists.
7.Revolving Sprinklers	$ 75.00	$ 38.00	$ 19.50	$133.00	$ 81.55	$ 54.46	Reasonable enough for most "irrigatable" crops. Installation labor can be largely done by proprietor
8.Perforated Pipe......	$ 50.00	$ 25.00	$ 17.50	$108.00	$ 68.55	$ 46.46	Good for row crops.Slightly cumbersome for small plots.No hired labor necessary
9.Porous Ho_e	$ 5.00	$ 2.50	$ 1.25	$ 63.00	$ 46.00	$ 35.21	No hired labor necessary.Very good for small plots

That table, too, can be clarified by several comments: 1. The "most-probable-'conveyance'-expenditure" figures are used in calculating the

"most-likely-installation cost" estimates; if a farmer already has a complete plumbing system — or other equipment which makes possible fewer new purchases — his expenditures for a complete system will be much less. 2. Charges are included only for the labor that is likely to be hired; as mentioned previously, most farmers do not regard as an expense the return which their own efforts should get. 3. Consideration of smaller plots within the one-acre category show that "distribution" installation costs — as well as "conveyance" equipment expenditures — usually become higher per acre unit as area decreases. 4. As has been explained in regards to our other figures, the above statistics are purely estimates, with a tendency to be high. 5. Despite the "average-and-judgment" nature of the figures, however, they do have complete validity in one respect: showing the relative expense of the various methods.

Following the procedure used after the other tables we will cite the few available records of actual small-garden irrigation experiences to show how closely they compare with our estimates. Staebner tells of a small revolving-sprinkler installation which would cost — including expenditure for a motor — $188 per acre. (Our estimate, without motor — $133) A bulletin of the South Dakota Extension Service sets $137.00 as the installation cost of a one-acre garden irrigation system using "furrow" distribution. (Subtracting the $75 item which the bulletin includes as the expenditure for a gasoline motor, the remainder of $62 compares

[illegible]

plots within the one-acre category show that "distribution" installation costs — as well as "conveyance" equipment expenditures — usually become higher per acre unit as area decreases. [illegible] above statistics are purely estimates, with a tendency to be [illegible] showing the relative expense of the various methods.

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favorably with our estimate of $63.50) A berry grower in Oregon paid $67.96 for the equipment to undertake furrow irrigation of an acre of his crop.

2. HAVING WORKED OUT INSTALLATION COSTS, it is possible to make estimates of operating expenses on one-acre plots or smaller. The same factors are involved in this process as were explained in presenting the approximations for larger-than-an-acre systems.

Operating Charges — Small Plots

Method	Kind of Total	1-acre Per year	1-acre Per inch	1/2-acre Per year	1/2-acre Per inch	1/4-acre Per year	1/4-acre Per inch	Per Acre on Large Plots Per year	Per Acre on Large Plots Acre inch	Remarks
Subirrigation	a	$60.97	$ 6.77	$39.92	$ 4.44	$22.91	$ 2.57	$77.15	$ 8.57	High depreciation. Low operating (cash) expenses. Rarely feasible
	b	27.67	3.07	16.06	1.67	9.32	1.04	30.90	3.43	
	c	9.25	1.03	5.68	.63	3.22	.36	10.65	1.19	
	d	8.35	.93	5.1[illegible]	.58	2.92	.32	10.24	1.14	
Furrow........	a	16.17	1.80	10.75	1.19	7.57	.84	22.72	2.52	Depreciation not so large. Very inexpensive. Good when there is slope
	b	9.54	1.06	5.94	.66	3.92	.44	12.90	1.43	
	c	5.73	.65	3.15	.35	1.81	.20	7.29	.81	
	d	4.03	.45	2.25	.25	1.31	.15	6.19	.69	
Border........	a	14.45	1.61	9.84	1.09	6.97	.77	20.87	2.32	Least expensive method. Not well adapted, however, to small plots
	b	8.45	.94	5.38	.60	3.53	.39	11.84	1.32	
	c	4.73	.53	2.65	.30	1.43	.16	6.33	.70	
	d	3.73	.41	2.10	.23	1.13	.13	5.73	.64	
Flood.........	a	15.22	1.69	10.17	1.13	7.20	.80	21.50	2.39	Not well adapted to small plots. Requires even slope and certain crops
	b	9.03	1.00	5.62	.62	3.71	.41	12.22	1.36	
	c	5.31	.59	2.89	.32	1.62	.18	6.72	.77	
	d	3.81	.42	2.14	.24	1.24	.14	5.97	.66	
Permanent Overhead......	a	49.82	5.54	28.57	3.17	16.96	1.88	56.49	6.28	Depreciation and labor rate relatively low. High installation cost makes operation expensive
	b	29.02	3.22	16.21	1.80	9.32	1.04	32.81	3.65	
	c	7.54	.84	4.00	.44	2.18	.24	9.76	1.08	
	d	6.64	.74	3.55	.39	1.96	.22	9.22	1.02	

Operating Charges — Small Plots
(Continued)

Method	Kind of total	1-acre Per year	1-acre Per inch	1/2-acre Per year	1/2-acre Per Inch	1/4-acre Per year	1/4-acre Per inch	Per Acre on Large Plots Per year	Per Acre on Large Plots Acre inch	Remarks
Portable Overhead........	a	$44.27	$ 4.92	$24.70	$ 2.74	$14.49	$ 1.61	$51.17	$ 5.69	Labor large item because of moving. Adapted to all terrains. Wears out faster than permanent
	b	24.87	2.76	13.54	1.50	7.40	.82	28.82	3.20	
	c	11.19	1.24	5.83	.65	2.81	.31	13.43	1.49	
	d	6.89	.77	3.68	.41	1.72	.19	11.18	1.24	
Portable Revolving Sprinklers..	a	31.42	3.49	17.80	1.98	11.21	1.25	38.37	4.26	Moving laterals requires much labor. Adapted to all terrains. Good for small plots
	b	18.12	2.01	9.64	1.07	5.87	.65	22.14	2.46	
	c	10.14	1.13	4.75	.53	2.60	.29	12.46	1.38	
	d	6.64	.74	2.95	.33	1.65	.18	10.57	1.07	
Perforated Pipe............	a	27.38	3.04	16.29	1.81	10.24	1.13	33.49	3.72	Moving pipes requires much labor. Little energy needed. Can be used only for row crops
	b	16.58	1.84	9.43	1.05	5.60	.62	19.69	2.19	
	c	10.10	1.12	5.32	.59	2.81	.31	11.44	1.27	
	d	4.90	.54	2.67	.30	1.49	.17	8.74	.97	
Porous Hose......	a	23.11	2.57	14.21	1.58	9.26	1.03	28.73	3.19	Much labor required to operate. Heavy rate of depreciation. Well adapted to small plots
	b	15.66	1.74	9.02	1.00	5.46	.61	18.15	2.02	
	c	11.88	1.32	6.26	.70	3.35	.37	12.60	1.51	
	d	5.38	.65	3.16	.35	1.75	.19	9.45	1.05	

Some of the comments applied to our other tabulations are among those which may help the reader in grasping the significance of the table on the two previous pages. As before, these figures are estimates with an intended bias towards being high but considerable accuracy in revealing the relative operating costs of various distributional methods. As before, these figures reemphasize the fact that supplemental irrigation is not to be had for picayunish sums; to be financially feasible it must effect marked increases in the production of high priced crops. Like large installations, the kitchen-garden systems tend to cost more, per given unit of land, as smaller areas are irrigated.

The other comments tend more towards being exclusively related to small-plot operation charges. In the first place, almost all the day-to-day labor is done by the irrigator himself without being considered an expense in money terms. Secondly, several methods seem somewhat unfeasible for irrigating the typical kitchen-garden installation because of high operating expenses, or lack of adaptability to various terrains or crops; subirrigation, permanent overhead irrigation, surface irrigation — particularly flood and border — may be in this group.

The previous table brings out at least one other important point: a comparison of operating costs on "one-acre-minus" plots and those on larger areas. This comparison reveals that —

despite the "smaller unit-higher cost" characteristics within both the large and small plot categories — a kitchen-garden system will probably cost less to establish and operate per acre than will a typical "larger-than-an-acre" installation. Such a situation prevails because the small systems are practically never put in unless water is very inexpensively available and partial equipment is already possessed by the irrigator.

As regards operating charges, the few published accounts of actual small plot irrigation contain little information. In "Irrigation in Western Washington" is a report of a six-tenths-acre permanent overhead installation with an operating cost of $3.46 per inch coverage of water. (Our figure for 1/2 acre was $3.17 per inch coverage of water.) "Garden Irrigation", a pamphlet put out by the Nebraska Agricultural College, says that the porous hose method — reckoned without depreciation, interest, and labor — will cost 36¢ for a one-inch coverage of water. (Our figure for 1/2 acre porous hose irrigation — reckoned as above — was 35¢ per inch coverage of water.) Calculations based on "Irrigating a One-Acre Garden", by Ralph L. Patty, would indicate $2.70 per acre-inch as the cost of irrigating a small plot by the furrow method, when all equipment has to be purchased. (Our figure for this method on one-acre plots — assuming that some equipment does not have to be bought —

is $1.80 per acre-inch.) Several statements in publications and letters sent out by the Skinner Company point towards a probable operating cost of $19.06 per season for a one-quarter-acre permanent overhead installation. (Our figure for a similar installation is $16.96.)

D. GROSS AND NET RETURNS

The figures given so far in this chapter have revealed that supplemental irrigation does not cost an insignificant amount. It remains for this section to show that the increased returns from the practice more than compensate for that substantial cost. In the following paragraphs and tables, therefore, we will attempt to translate the crop results of irrigation — larger quantity, better quality, more numerous crops per season, etc. — into monetary terms corresponding to the cost statistics above.

1. The literature of the field is abundant with references to this phase of the subject — the increased profits which irrigators have received. Application of the porous hose method to a forty-acre orchard in Ohio brought a net return of $90 per acre, $66.80 more per acre than was secured on non-irrigated land nearby. A. S. Colby, pomologist of Illinois Agriculture College, states that irrigation increases the value of strawberries at least $50 — enough to make the overhead system profitable — even in years when rainfall conditions are best and berry prices are lowest. Various

check-plot experiments conducted at Ames, Iowa indicate that supplemental watering of tomatoes, onions, carrots and other garden plants will usually increase profits by more than 50 per cent. A.G.B. Bouget, professor of vegetable gardening in the Oregon State Agricultural College, found that irrigation of the following vegetables produced consistent increases in net value per acre: sweet corn $79.00, late cabbage $101.50, hubbard squash $104.70. Another Oregon publication — based on twenty-five years of study of supplemental irrigation on ten different crops in the humid part of the state — gives $8.80 as the average net increase in profits from using artificial watering. The following table summarizes the important facts, concerned with monetary return, on the preceding investigations and others.

Results of Supplemental Irrigation, Individual Experiments

Crop	Plot Description: Size	Distance from water	Terrain	Soil	Method	Crop increase per acre	Gross cash gain per acre	Net profit per acre	Gain in net profit per acre	State	Remarks
Spinach......	4 ac.	?	Level	Sandy	Permanent overhead	233 crates	$ 90.87		$ 30.88	N.J.	Av. of 7 yrs.
Radishes....	1/15 ac		Level	Heavy loam	Permanent overhead	28%				Iowa	Av. of 6 yrs.
Carrots.....	1/15 ac		Level	Heavy loam	Permanent overhead	70%				Iowa	Av. of 5 yrs.
Carrots.....			Rolling	Sandy	Revolving sprinkler	23.8 to 195%				Ore.	Results in especially dry year
Beets.......			Rolling	Sandy	Revolving sprinkler	4.6 to 144%				Ore.	Results in especially dry year
Beets.......			Sloping	Sandy loam	Furrow	4.6 to 42%	$ 23.15	$ 44.29	$ 9.39	Ore.	Av. of 25 yrs.
Beets.......	1/15 ac.		Level	Heavy loam	Permanent overhead	72%				Iowa	Av. of 6 yrs.

Results of Supplemental Irrigation, Individual Experiments
(continued)

Crop	Plot Description: Size	Distance from water	Terrain	Soil	Method	Crop increase per acre	Gross cash gain per acre	Net profit per acre	Gain in net profit per acre	State	Remarks
Kale........			Sloping	Silt loam	Furrow	3.4 to 32%	$ 17.00			Wash.	Av. of 20 yrs
Squash......	1 ac.		Level	Sandy loam	Permanent overhead	4 to 66 2/3%	$120.00		$104.70	N.J.	Only labor and energy figured in cost
Cabbage.....	1 ac.		Rolling	Sandy	Permanent overhead	5 to 75%	$120.00		$101.50	Ind.	Same as item above
Cabbage.....			Sloping		Furrow				$208.40	Ore.	Same
Sweet Corn..			Level		Flood				$ 58.50	Ore.	Same
Sweet Corn..	1 ac.	400'	Sloping		Furrow		$101.00		$ 79.00	Wash.	Same
Sweet corn..	1 ac.				Permanent overhead	645 dz. 110%	$ 97.75		$ 85.18	Wash.	Same
Tomatoes....				Heavy loam	Permanent overhead	500%				Ala.	Unusually high gain

Results of Supplemental Irrigation, Individual Experiments
(continued)

Crop	Plot Description: Size	Distance from water	Terrain	Soil	Method	Crop increase per acre	Gross cash gain per acre	Net profit per acre	Gain in net profit per acre	State	Remarks
Tomatoes...				Sandy loam	Permanent overhead	5 to				N.J.	Unusually high gain 4 yr.av.
Tomatoes...					Permanent overhead	4 to				Wisc.	Av.gain per yr. for 7 yrs.
Tomatoes...	6/10 ac.	250'	Level	Clay loam	Permanent overhead	39%	$144.70		$87.10	Ore.	
Tomatoes...	1/15 ac.		Level	Heavy loam	Permanent overhead	42%				Io.	Av.gain per yr. for 6 yrs.
Onions.....					Flood	153 bu. 75%				Mich.	Quality much improved
Onions.....	1/15 ac.		Level	Heavy loam	Permanent overhead	70%				Io.	Av.per yr.for 6 yrs.
Beans......			Sloping	Sandy loam	Furrow	4.91 bu. 48%	$ 14.73	$21.87	$10.91	Ore.	Av.of 21 yrs.

Results of Supplemental Irrigation. Individual Experiments
(Continued)

Crop	Plot Description				Method	Crop increase per acre	Gross cash gain per acre	Net profit per acre	Gain in net profit per acre	State	Remarks
	Size	Distance from water	Terrain	Soil							
String beans.					Revolving sprinkler	8122 lbs. 340%				Ore.	Unusually good results
Lima beans...			Level	Heavy loam	Permanent overhead	None				Io.	Good yield without irrigating
Potatoes.....			Level	Muck	Subirrigation	134 bu. 63%				Ohio	Increase in quality
Potatoes.....			Level	Muck	Permanent overhead	123 bu. 61%				Ohio	Same
Potatoes.....		450'	Sloping	Sandy loam	Furrow	59 bu. 41%	$29.46	$45.27	$18.27	Ore.	Same
Potatoes.....	2.3				Furrow	233.8 bu. 230%				Neb.	Semi-arid region
Corn.........		450'	Sloping	Sandy	Furrow	2.46 to 38%	$12.30	$13.93	$ 1.58	Ore.	Not one of best adapted crops

Results of Supplemental Irrigation, Individual Experiments
(Continued)

Crop	Plot Description: Size	Distance from water	Terrain	Soil	Method	Crop increase per acre	Gross cash gain per acre	Net profit per acre	Gain in net profit per acre	State	Remarks
Muskmellon.					Furrow	72.4%				Io.	
Sweet potatoes...					Furrow	35.3%				Io.	Decided increase in quality
Strawberries.					Permanent overhead	2582 lbs. 82.4%	$203.32	$181.21	$ 94.81	Ore.	
Strawberries.					Porous hose	62%				Mich.	More net because less cost
Raspberries.					Permanent overhead	2599 58.4%	$123.10	$261.76	$120.35	Ore.	Adapted well to irrigation
Alfalfa.....						[illegible] to 61%	$ 22.10	$ 28.38	$ 7.18	Ore.	Not so well adapted in more humid states

The most obvious and most important conclusion made plain by the above tabulation is that supplemental irrigation is generally profitable on a very wide range of crops. This holds quite true no matter what the method, the type of soil, or the section of the humid regions. If the figures we have compiled are representative, there appears to be an average increase in crop yield of 78 per cent and in net profit per acre of $66.21.

Paralleling that statement of general profitableness, however, it seems well to "point up" several characteristics of the table which may indicate that a good share of the individual items are slightly too optimistic. In the first place, more of the profit figures have been calculated without considering any charges but labor and energy. Secondly, chiefly the more successful undertakings in humid region irrigation have found their way into print and subsequently into the above tabulation. Thirdly, much of the material in the table has resulted from agricultural research experiments conducted with more careful cultivational practices than most run-of-the-mill growers feel obliged to employ. In a later table of "average-and-judgment" estimates of the returns from irrigation, those three small modifying considerations are given some weight.

Another conclusion for which the above tabulation furnishes some basis is that supplemental irrigation — granting the general

benefits of the practice -- raises the financial returns from some crops more than it does from others. Truck-crops -- particularly spinach, lettuce, beets, carrots, onions, string beans, etc. -- and fruits -- strawberries, raspberries and apples for example -- are very well suited to artificial watering. Field crops -- like oats, buckwheat, corn, etc. -- and exceptionally hardy plants -- such as lima beans, asparagus, peppers, etc. -- usually do not benefit greatly from irrigation in normal seasons. Putting it briefly, crops which sell for high prices in eager markets or fail badly and quickly in time of droughts, are the ones to which supplemental watering can be most profitably devoted.

Still another characteristic of the financial returns from supplemental irrigation is the great number of matters, besides kind of crop grown, which influence the degree of <u>increased</u> profit. Among the most important of these matters are: method of distribution, amount of natural precipitation, area of the plot being irrigated, distance of the plot from water. Other determining factors include the type of soil and terrain, the length and warmth of the growing season, the general cultivational skill and irrigation experience of the grower, the interest rate and kind of energy used.

Because the number and variability of these influencing factors makes the increase on profits from supplemental irrigation anything from 1 per cent to 1,000 per cent, not too

much significance should be attached to any possible publications of <u>average or most likely</u> returns. Such a tabulation for certain crops is presented below, however, since it enables us — through the medium of "average-and-judgment" estimates — to give some weight to minor considerations modifying here and there the optimistic picture presented by the above citation of actual cases and since it furnishes a needed tool for comparing returns with "average-and-justment" estimates of "most likely operating costs". This table is based mainly on actual figures — those above and others — and presents a carefully considered judgment of the most likely returns from irrigating under the most likely conditions of soil, weather, etc. Things to keep in mind while considering that table include these: figures represent the optimum relationship between the decreasing returns from more water and decreasing cost of more water; the "returns" from kitchen-garden installations may manifest themselves as savings on what has to be spent for food or as cash when there is a roadside stand.

Returns From Supplemental Irrigation

Crop	Designation of figures	Sub-irrigation	Furrow	Border	Flood	Permanent overhead	Portable overhead	Revolving sprinkler	Perforated pipe	Porous hose	Water[1]
Spinach	2 Gross, P.A.I.	$ 11.40	$ 7.00	$	$	$ 10.15	$ 10.00	$ 9.60	$	$ 8.10	7
	3 Com.Cost P.A.I.	10.55	3.10			7.73	7.00	5.24		3.93	
	4 Com.Net P.A.I.	.85	3.90			2.42	3.00	4.36		4.17	
	5 Com.Net P.A.	5.95	27.30			16.94	21.00	30.52		29.19	
	6 K.G.Cost P.A.I.	8.33	2.22			6.81	5.95	4.30		3.16	
	7 K.G.Net P.A.I.	3.07	4.78			3.34	4.05	5.30		4.94	
	8 K.G.Net P.A.	21.49	33.46			23.38	28.35	37.10		34.58	

1. Water — Optimum inches of irrigation water during typical season.
2. Gross, P.A.I. — Likely gross increase in returns per acre-inch of irrigation.
3. Com.Cost, P.A.I. — Likely cost for acre-inch of water on commercial-sized plots.
4. Com.Net, P.A.I. — Likely net increase in returns per acre-inch on commercial-sized plots.
5. Com.Net, P.A. — Likely net increase in returns per acre on commercial-sized plots.
6. K.G. Cost, P.A.I. — Likely cost for acre-inch of water on "kitchen-garden" plots.
7. K.G. Net, P.A.I. — Likely net increase in returns per acre-inch on "kitchen-garden" plots.
8. K.G. Net, P.A. — Likely net increase in returns per acre on "kitchen-garden" plots.

Returns From Supplemental Irrigation
(Continued)

Crop	Designation of figures	Sub-irrigation	Furrow	Border	Flood	Permanent overhead	Portable overhead	Revolving sprinkler	Perforated pipe	Porous hose	Water[1]
Radishes	Gross, P.A.I.	$ 6.20	$ 5.60			$ 6.80	$ 6.60	$ 6.60		$ 6.50	
	Com.Cost P.A.I.	10.55	3.10			7.73	7.00	5.24		3.93	
	Com.Net P.A.I.	-4.35	2.50			-.93	-.40	1.36		2.57	
	Com.Net P.A.	-30.45	17.50			-6.51	-2.80	9.52		17.99	
	K.G.Cost P.A.I.	8.33	2.22			6.81	5.95	4.30		3.16	
	K.G.Net P.A.I.	- 2.13	3.38			-.01	.65	2.30		3.34	
	K.G.Net PA.	-14.91	23.66			-.07	4.55	16.10		23.38	
Carrots	Gross, P.A.I.	12.50	9.00			13.15	12.95	13.00		11.95	
	Com.Cost P.A.I.	7.82	2.30			5.73	5.19	3.89		2.91	
	Com.Net P.A.I.	4.68	6.70			7.42	7.76	9.11		9.04	
	Com.Net P.A.	46.80	67.00			74.20	77.60	91.10		90.40	
	K.G.Cost P.A.I.	6.18	1.64			5.05	4.49	3.18		2.34	
	K.G.Net P.A.I.	6.32	7.36			8.10	8.46	9.82		9.61	
	K.G.Net P.A.	63.20	73.60			81.00	84.60	98.20		96.10	

Returns From Supplemental Irrigation
(Continued)

Crop	Designation of figures	Sub-irrigation	Furrow	Border	Flood	Permanent overhear	Portable overhead	Revolving sprinkler	Perforated pipe	Porous hose	Water
Beets	Gross, P.A.I.	$ 10.90	$ 9.00	$ 8.50	$ 8.50	$ 11.10	$ 10.90	$ 11.00	$ 9.40	$ 9.60	7
	Com.Cost P.A.I.	10.55	3.10	2.85	2.94	7.73	7.00	5.24	4.58	3.93	
	Com.Net P.A.I.	.35	5.90	5.65	5.56	3.37	3.90	5.76	4.82	5.67	
	Com.Net P.A.	2.45	41.30	38.85	38.92	23.59	27.30	40.32	33.74	39.69	
	K.G.Cost P.A.I.	8.33	2.22	1.98	2.08	6.81	5.95	4.30	3.74	3.16	
	K.G.Net P.A.I.	2.57	6.78	6.52	6.42	4.29	4.95	6.70	5.66	6.44	
	K.G.Net P.A.	17.99	47.46	45.64	44.94	30.03	34.65	46.90	39.62	45.08	
Kale	Gross, P.A.I.	7.15	6.65	6.55	6.47	7.00	6.85	6.90	6.20	6.40	7
	Com.Cost P.A.I.	10.55	3.10	2.85	2.94	7.73	7.00	5.24	4.58	3.93	
	Com.Net P.A.I.	-3.40	3.55	3.70	3.53	-.73	-.15	1.66	1.62	2.47	
	Com.Net P.A.	-23.80	24.85	25.90	31.77	-5.11	-1.05	11.62	11.34	17.29	
	K.G.Cost P.A.I.	8.33	2.22	1.98	2.08	6.81	5.95	4.30	3.74	3.16	
	K.G.Net P.A.I.	-1.18	4.43	4.57	4.39	.19	.90	2.60	2.46	3.24	
	K.G.Net P.A.	-8.26	31.01	31.99	30.73	1.33	6.30	18.20	17.22	22.68	

Returns From Supplemental Irrigation
(Continued)

Crop	Designation of figures	Sub-irrigation	Furrow	Border	Flood	Permanent overhead	Portable overhead	Revolving sprinkler	Perforated pipe	Porous hose	Water
Squash	Gross, P.A.I.	$ 7.90	$	$	$	$ 9.00	$ 8.70	$ 8.85	$	$	9
	Com.Cost P.A.I.	8.57				6.28	5.69	4.26			
	Com.Net P.A.I.	-.67				2.72	3.01	4.59			
	Com.Net P.A.	- 6.03				24.48	27.09	41.31			
	K.G.Cost P.A.I.	6.77				5.54	4.92	3.49			
	K.G.Net P.A.I.	1.13				3.46	3.78	5.36			
	K.G.Net P.A.	10.17				31.14	34.02	48.24			
Cabbage	Gross, P.A.I.	8.20	7.95	8.00	8.00	9.15	9.00	9.10	8.40	8.55	9
	Com.Cost P.A.I.	8.57	2.52	2.32	2.39	6.28	5.69	4.26	3.72	3.19	
	Com.Net P.A.I.	-.37	5.43	5.68	5.61	2.87	3.31	4.84	4.68	5.36	
	Com.Net P.A.	-3.33	48.87	51.12	50.49	25.83	29.79	43.56	42.12	48.24	
	K.G.Cost P.A.I.	6.77	1.80	1.61	1.69	5.54	4.92	3.49	3.04	2.57	
	K.G.Net P.A.I.	1.43	6.15	6.39	6.31	3.61	4.08	5.61	5.36	5.98	
	K.G.Net P.A.	12.87	55.35	57.51	56.79	32.49	36.72	50.49	48.24	53.82	

Returns From Supplemental Irrigation
(Continued)

Crop	Designation of Figures	Sub-irrigation	Furrow	Border	Flood	Permanent overhead	Portable overhead	Revolving sprinkler	Perforated pipe	Porous hose	Water
Sweet Corn	Gross, P.A.I.	$ 7.20	$ 7.60	$ 7.45	$ 7.40	$ 8.00	$ 7.20		$ 7.90	$ 8.00	9
	Com.Cost P.A.I.	8.57	2.52	2.32	2.39	6.28	5.69		3.72	3.19	
	Com.Net P.A.I.	-1.37	5.08	5.23	5.01	1.72	1.51		4.18	4.81	
	Com.Net P.A.	-12.33	45.72	47.07	45.09	15.48	13.59		37.62	43.29	
	K.G.Cost P.A.I.	6.77	1.80	1.61	1.69	5.54	4.92		3.04	2.57	
	K.G.Net P.A.I.	.43	5.80	5.84	5.71	2.46	2.28		4.86	5.43	
	K.G.Net P.A.	3.87	52.20	52.56	51.39	22.14	20.52		43.74	48.87	
Tomatoes	Gross, P.A.I.	6.90	9.70			10.45	10.30	$ 10.50	9.80	10.00	10
	Com.Cost P.A.I.	7.82	2.30			5.73	5.19	3.89	3.39	1.91	
	Com.Net P.A.I.	-.92	7.40			4.72	5.11	6.61	6.41	7.09	
	Com.Net P.A.	-9.20	74.00			47.20	51.10	66.10	64.10	70.90	
	K.G.Cost P.A.I.	6.18	1.64			5.05	4.49	3.18	2.77	2.34	
	K.G.Net P.A.I.	.72	8.06			5.40	5.81	7.32	7.03	7.66	
	K.G.Net P.A.	7.20	80.60			54.00	58.10	73.20	70.30	76.60	

Returns From Supplemental Irrigation
(Continued)

Crop	Designation of figures	Sub-irrigation	Furrow	Border	Flood	Permanent overhead	Portable overhead	Revolving sprinkler	Perforated pipe	Porous hose	Water
Onions	Gross, P.A.I.	$ 8.50	$ 9.95	$ 9.95	$ 9.95	$ 10.95	$ 10.65	$ 10.90	$ 9.10	$ 10.00	9
	Com.Cost, P.A.I.	8.57	2.52	2.32	2.39	6.28	5.69	4.26	3.72	3.19	
	Com.Net P.A.I.	-.07	7.43	7.63	7.56	4.67	4.96	6.64	5.38	6.81	
	Com.Net. P.A.	-.63	66.87	68.67	68.04	42.03	44.64	59.76	48.42	61.29	
	K.G.Cost P.A.I.	6.77	1.80	1.61	1.69	5.54	4.92	3.49	3.04	2.57	
	K.G.Net P.A.I.	1.73	8.15	8.34	8.26	5.41	5.73	7.41	6.06	7.43	
	K.G.Net P.A.	15.57	73.55	75.06	74.34	48.69	51.57	66.69	54.54	66.87	
String beans	Gross P.A.I.	8.40	11.00			11.40	11.00	11.20	10.90	11.00	7
	Com.Cost P.A.I.	10.55	3.10			7.73	7.00	5.24	4.58	3.93	
	Com.Net P.A.I.	-2.15	7.90			3.67	4.00	5.96	6.32	7.07	
	Com.Net P.A.	-15.05	55.30			25.69	28.00	41.72	44.24	49.49	
	K.G.Cost P.A.I.	8.33	2.22			6.81	5.95	4.30	3.74	3.16	
	K.G.Net P.A.I.	.07	8.78			4.59	5.05	6.90	7.16	7.84	
	K.G.Net P.A.	.49	61.46			32.13	35.35	48.30	50.12	54.88	

Returns From Supplemental Irrigation
(Continued)

Crop	Designation of figures	Sub-irrigation	Furrow	Border	Flood	Permanent overhead	Portable overhead	Revolving sprinkler	Perforated pipe	Porous hose	Water
Lima beans	Gross, P.A.I.	$ .50	$ .90	$ .75	$ .75	$ 1.50	$ 1.05	$ 1.20	$ .80	$ .95	6
	Com.Cost P.A.I.	11.84	3.84	3.21	3.30	8.67	7.86	5.88	5.14	4.41	
	Com.Net P.A.I.	-11.34	-2.58	-2.46	-2.55	-7.17	-6.81	-4.68	-4.34	-3.46	
	Com.Net P.A.	-68.04	-15.48	-14.76	-15.30	-43.02	-40.86	-28.08	-26.04	-20.76	
	K.G.Cost P.A.I.	9.35	2.49	2.22	2.33	7.65	6.80	4.82	4.20	3.55	
	K.G.Net P.A.I.	-8.85	-1.59	-1.47	-1.58	-6.15	-5.75	-3.62	-[illegible].40	-2.60	
	K.G.Net P.A.	-53.10	-9.54	-8.82	-9.48	-36.90	-34.50	-21.72	-20.40	-15.60	
Potatoes	Gross, P.A.I.	7.70	7.80	7.80	7.80	8.30	8.10	8.30	7.90	8.00	11
	Com.Cost P.A.I.	7.19	2.11	1.95	2.00	5.27	4.77	3.57	3.12	2.68	
	Com.Net P.A.I.	.51	5.69	5.85	5.80	3.03	3.33	4.73	4.78	5.32	
	Com.Net P.A.	5.61	62.59	64.35	63.80	33.33	36.63	52.03	52.58	58.52	
	K.G.Cost P.A.I.	5.68	1.51	1.35	1.42	4.65	4.13	2.93	2.55	2.16	
	K.G.Net P.A.I.	2.02	6.29	6.45	6.38	3.65	3.97	5.37	5.35	5.84	
	K.G.Net P.A.	22.22	69.19	70.95	70.18	40.15	43.67	59.07	58.85	62.24	

Returns From Supplemental Irrigation
(Continued)

Crop	Designation of figures	Sub-irrigation	Furrow	Border	Flood	Permanent overhead	Portable overhead	Revolving sprinkler	Perforated pipe	Porous hose	Water
Corn	Gross, P.A.I.	$ .50	$ 2.00	$ 2.00	$ 2.00				$ 2.35	$ 1.25	9
	Com.Cost P.A.I.	8.57	2.52	2.32	2.39				3.72	3.19	
	Com.Net P.A.I.	-8.07	-.52	-.32	-.39				-1.37	-.94	
	Com.Net P.A.	-72.63	-4.68	-2.88	-3.51				-12.33	-8.46	
	K.G.Cost P.A.I.	6.77	1.80	1.61	1.69				3.04	2.57	
	K.G.Net P.A.I.	-6.27	.20	.39	.31				-.69	-.32	
	K.G.Net P.A.	-56.43	1.80	3.51	2.79				-6.21	-2.88	
Muskmellon	Gross, P.A.I.	6.16	6.00	5.90	5.90	$ 6.30	$ 6.25	$ 6.30	4.00	5.50	10
	Com.Cost P.A.I.	7.82	2.30	2.12	2.18	5.73	5.19	3.89	3.39	1.91	
	Com.Net P.A.I.	-1.66	3.70	3.78	3.72	.57	1.06	2.41	.61	2.59	
	Com.Net P.A.	-16.60	37.00	37.80	37.20	5.70	10.60	24.10	6.10	2590	
	K.G.Cost P.A.I.	6.18	1.64	1.47	1.54	5.05	4.49	3.18	2.77	2.34	
	K.G.Net P.A.I.	-.02	4.36	4.43	4.36	1.25	1.76	3.12	1.23	3.16	
	K.G.Net P.A.	-.20	43.60	44.30	43.60	12.50	17.60	31.20	12.30	31.60	

Returns From Supplemental Irrigation
(Continued)

Crop	Designation of figures	Sub-irrigation	Furrow	Border	Flood	Permanent overhead	Portable overhead	Revolving sprinkler	Perforated pipe	Porous hose	Water
Sweet potato	Gross, P.A.I.	$ 5.80	$ 6.05	$ 6.00	$ 6.00	$ 6.20	$ 6.10	$ 6.20	$ 5.00	$ 5.60	10
	Com.Cost P.A.I.	7.82	2.30	2.12	2.18	5.73	5.19	3.89	3.39	2.91	
	Com.Net P.A.I.	-2.02	3.75	3.88	3.82	.47	.91	2.31	1.61	2.69	
	Com.Net P.A.	-20.20	37.50	38.80	38.20	4.70	9.10	23.10	16.10	26.90	
	K.G.Cost P.A.I.	6.18	1.64	1.47	1.54	5.05	4.49	3.18	2.77	2.34	
	K.G.Net P.A.I.	-.38	4.41	4.53	4.46	1.15	1.61	3.02	2.23	3.26	
	K.G.Net P.A.	-3.80	44.10	45.30	44.60	11.50	16.10	30.20	22.30	32.60	
Strawberries	Gross, P.A.I.	7.00	15.80	14.00	14.00	18.00	17.70	17.90	14.00	16.40	9
	Com.Cost P.A.I.	8.57	2.52	2.32	2.39	6.28	5.69	4.26	3.72	3.19	
	Com.Net P.A.I.	-1.57	13.28	11.68	11.61	11.72	12.01	13.46	10.28	13.21	
	Com.Net P.A.	-14.13	119.52	105.12	104.49	105.48	108.09	122.76	92.52	118.89	
	K.G.Cost P.A.I.	6.77	1.80	1.61	1.69	5.54	4.92	3.49	3.04	2.57	
	K.G.Net P.A.I.	.23	14.00	12.39	12.31	12.46	12.78	14.41	10.96	13.83	
	K.G.Net P.A.	2.07	126.00	111.51	110.79	112.14	115.02	129.69	98.64	124.47	

Returns From Supplemental Irrigation
(Continued)

Crop	Designation of figures	Sub-irrigation	Furrow	Border	Flood	Permanent overhead	Portable overhead	Revolving sprinkler	Perforated pipe	Porous hose	Water
Raspberries	Gross, P.A.I.	$ 6.00	$ 11.00	$ 10.75	$ 10.75	$ 12.30	$ 11.90	$ 12.20	$ 11.00	$ 11.80	10
	Com.Cost. P.A.I.	7.82	2.30	2.12	2.18	5.73	5.19	3.89	3.39	2.91	
	Com.Net P.A.I.	-1.82	8.70	8.63	8.56	6.57	6.71	8.31	7.61	8.89	
	Com.Net P.A.	-18.20	87.00	86.30	85.60	65.70	67.10	83.10	76.10	88.90	
	K.G.Cost P.A.I.	6.18	1.64	1.47	1.54	5.05	4.49	3.18	2.77	2.34	
	K.G.Net P.A.I.	-.18	9.36	9.28	9.21	7.25	7.41	9.02	8.23	9.46	
	K.G.Net P.A.	-1.80	93.60	92.80	92.10	72.50	74.10	90.20	82.30	94.60	
Alfalfa	Gross, P.A.I.	2.15				2.20	2.10	2.20	1.90	2.15	12
	Com.Cost P.A.I.	6.65				4.87	4.41	3,30	2.89	2.47	
	Com.Net P.A.I.	-4.50				-2.67	-2.31	-1.10	-.99	-.32	
	Com.Net P.A.	-54.00				-32.04	-27.72	-13.20	-11.88	-3.84	
	K.G.Cost P.A.I.	5.25				4.30	3.82	2.71	2.36	1.99	
	K.G.Net P.A.I.	-3.10				-2.10	-1.72	- .51	-.46	.16	
	K.G.Net P.A.	-37.20				-25.20	-20.64	-6.12	-5.52	1.92	

Returns From Supplemental Irrigation
(Continued)

Crop	Designation of figures	Sub-irrigation	Furrow	Border	Flood	Permanent overhead	Portable overhead	Revolving sprinkler	Perforated pipe	Porous hose	Water
Apples	Gross, P.A.I.		$ 6.50	$ 6.60	$ 6.60	[illegible]			$ 6.50	$ 6.50	12
	Com.Cost P.A.I.		1.93	1.80	1.85	[illegible]			2.89	2.47	
	Com.Net P.A.I.		4.57	4.80	4.75	[illegible]			3.61	4.03	
	Com.Net P.A.		54.84	57.60	57.00	[illegible]			43.32	48.36	
	K.G.Cost P.A.I.		1.40	1.25	1.31				2.36	1.99	
	K.G.Net P.A.I.		5.10	5.35	5.29				4.14	4.51	
	K.G.Net P.A.		61.20	64.20	63.48				49.68	54.12	
Averages	Gross, P.A.I.	$ 6.90	7.75	7.25	7.24	$ 9.00	$ 8.74	$ 8.94	7.20	7.85	9
	Com.Cost P.A.I.	8.89	2.62	2.35	2.42	6.53	5.91	4.44	3.75	3.27	
	Com.Net P.A.I.	-1.99	5.13	4.90	4.82	2.47	2.83	4.50	3.45	4.58	
	Com-Net P.A.	-15.11	47.25	46.46	46.29	23.54	26.62	38.66	32.57	41.69	
	K.G.Cost P.A.I.	7.02	1.87	1.63	1.71	5.76	5.09	3.64	3.06	2.63	
	K.G.Net P.A.I.	-.13	5.88	5.62	5.53	3.24	3.65	5.30	4.14	5.22	
	K.G.Net P.A.	-.65	53.46	52.81	52.02	30.16	33.67	48.00	38.48	47.79	

Returns From Supplemental Irrigation
(Continued)

Crop	Designation of figures	Sub-irrigation	Furrow	Border	Flood	Permanent overhead	Portable overhead	Revolving sprinkler	Perforated pipe	Porous hose	Water
	Gross, P.A.I.					$ 7.87					
	Com.Cost P.A.I.					4.46					
	Com.Net P.A.I.					3.41					
	Com.Net P.A.					31.97					
Combined averages	K.G.Cost P.A.I.					3.60					
	K.G.Net P.A.I.					4.27					
	K.G.Net P.A.					39.53					

VII. PROBABLE DEVELOPMENTS

Having analyzed the financial feasibility, load possibilities, and other matters concerning supplemental irrigation, it now remains only to suggest the probable future developments of this very desirable cultivational practice. What distributional systems are likely to be used most? What sections will become the lands of most supplemental irrigation? What overall factors are making for extensive development of the practice? Those are some of the questions which should be answered.

A. PRESENT EXTENT

Supplemental irrigation so far has received nothing like the attention which it merits. The leading states at this writing are Ohio where there are many small installations for home vegetable gardens and some large ones for orchards, Michigan where there is extensive potato irrigation by the porous hose technique, and New Jersey where numerous truck gardens are watered by the overhead sprinkler system. In the South almost nothing has been done and this is likewise true of New England. During the drought years of the early thirties, the practice was given considerable impetus but since then — because nobody

has been enough concerned to "push" strongly — there has been very little increase. Estimates of supplemental irrigation acreage at present are contained in a table by Staebner:

Estimate of Acres Irrigated

	1931	1936
Minnesota	150	895
Wisconsin	40	340
Michigan	2000	7600
Iowa	1000	1000
Illinois	250	630
Indiana	1756	550
Ohio	500	10,000
Delaware		10
Pennsylvania		300
New York		1825
Maryland	5700	1150
New Jersey		6000
Connecticut		355
Massachusetts		2000
Rhode Island		200
Maine		98
Vermont		7
Total	11,396	33,060

B. FAVORABLE FACTORS

Underlying the long-range course of supplemental irrigation development, there are several fundamental factors which point towards expansion of the practice. In the first place, the tendency of rainfall is to become less and less; this trend will probably continue for a period of years if the predictions of Weather Bureau technicians are to be believed. Secondly agricultural in the long

run will become much more intensive, with many marginal lands put back to forests and many more crops grown on the diminished acreage. Thirdly, the farms of America are becoming increasingly electrified and with this comes the power which makes irrigation possible.

C. SECTIONAL DEVELOPMENT

In Chapter III an anlysis of sectional potentialities was made in reference to REA load and the same factors apply here are a larger scale. The South will be slow to take up the practice because of low incomes, plentiful rainfall, prevalence of cotton and tobacco farming, etc. The East will probably use the overhead sprinkler and revolving sprinkler systems more and more for truck growing and kitchen gardens. In the mid-West, there is possibility of vast expansion along the lines of irrigation for fruits, corn, table vegetables, potatoes, etc.; porous hose and revolving sprinkler systems will probably be most used. In the "west-of-the-Cascades" section, there will be a few large consumption installations which use the furrow or other surface systems.

D. DISTRIBUTIONAL TECHNIQUES

As hinted above, various distribution systems will probably be used in different sections. The most all-round useful, productive

and economical methods, however, seem to be porous hose and revolving sprinkler. The permanent overhead will continue to be used for large truck installations where high-priced vegetables are grown. Surface methods will be applied in orchards and in flat level country where coarser crops, like corn and potatoes are raised. Sub-irrigation — as the figures in the last chapter plainly showed — is feasible almost everywhere except for very expensive crops grown on the ideal soil.

E. OTHER DEVELOPMENTS

There are various other trends in this supplemental irrigation business and among them are the following. It is likely that much watering will be done at night — particularly on the smaller installations — by having the irrigator turn on the system when he retires and turn it off when he gets up. In the merchandising field there is the development of the "package selling" technique. The increase in kitchen gardens as the nation becomes more and more suburban is likewise important.

VIII. AN REA PROGRAM

The details of any program which will take advantage of the large potential irrigation load and give the farmers the advantages of supplemental watering, is the business of the Utilization Division. As a concluding section to this paper, however, the broad outlines of such a program are suggested. It is felt that the adoption of some such program would stabilize and increase the load of those many projects which are located in areas favorable to crop-watering.

A. FURTHER RESEARCH

First of all, the organization should get some trial installations on farms in various favorable sections. By this means the load and personal feasibility of the practice could be checked with actual experience. It is suggested that some mid-West states — like Ohio and Indiana — be used for this sampling.

On the technical side of the subject, moreover, much more could be done. Now that REA is in Agriculture, it might be possible to have one of the old-line bureaus conduct check-plot experiments. Various methods would be tested for cost, effectiveness, load, durability, etc. Various crops would be tested, also, to see whether or not supplemental water did enough good to merit widespread use. Perhaps some of the student engineers could develop a study of the technical side.

VIII. [illegible]

The details of any program which will take advantage of the [illegible] of supplemental watering, is the business of the Utilization Division. [illegible] however, the broad outlines of such a program are suggested. It is felt that [illegible]

1. [illegible]

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[illegible] Various methods would be tested for cost, effectiveness, load, [illegible]ability, etc. Various crops would be tested, also, to see whether [illegible]

B. SYSTEMS TO EMPHASIZE

Revolving sprinkler and porous hose seem like the most feasible systems for REA to emphasize in any selling campaign. These methods are both inexpensive and efficient and are good for both small and large installations. They have, also, a portable feature which works in well with crop rotation and with stretching applications out over a period of days.

In the beginning, it should be mentioned, REA should go after numerous small installations. These are easier to "sell" than the big ones and use just as much current. The small installations, moreover, fit in well with the plumbing campaign since the same pump and motor can be used for both things. If the kitchen-garden units prove profitable, irrigators will take quickly to the larger commercial installations.

C. LITERATURE

A supplemental irrigation plan should proceed along the same lines as past utilization campaigns, as far as the publications phase is concerned. There might well be articles in the RE News and various four-page leaflets. Also, a manual for project superintendents — such as was issued for the brooder campaign — also would be very helpful. The News articles could very well begin at once.

D. PURCHASING

Since supplemental irrigation requires considerable initial expenditure, some financing plan will be necessary in most cases. Loans to the cooperatives and thence to the members — as is done for wiring and plumbing — would be entirely feasible. REA may not have to do this directly, however, for the E.F.H.A. is expressly set up for such loans.

Another feature of the purchasing angle should be cooperative buying. Systems like the overhead and revolving sprinkler are made by wide-awake business concerns and they doubtless would give considerable reduction for large orders. Project superintendents would be asked to sign twenty members for similar units of kitchen-garden size and then would put in the order as one demand.

Another purchasing stimulant would come from emphasis on the package merchandising idea. Some revolving-sprinkler manufacturers are already selling their products in this manner and REA might be able to urge others into doing the same things. Installations would come to the farmer ready for easy assembly without the necessity of engineering advise.

E. MISCELLANEOUS

Other phases of the program would be many. Field repre-

sentatives should be asked to feature supplemental irrigation in their talks with superintendents and directors. Assistance might be had from numerous other agencies in the Department of Agriculture, extension agents for example. Certain areas should be picked for extensive "selling", like the Iowa range campaign, etc. By doing the things suggested above and others, REA might in several years increase the load of its projects by more than ten per cent and increase to income of irrigating members by a like or greater amount.

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